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ELECTRET NOISECANCELLING MICROPHONE.(U)

APR 78 D W MACKIERNAN, A P WOODWARD DAAB07-76-C-0175

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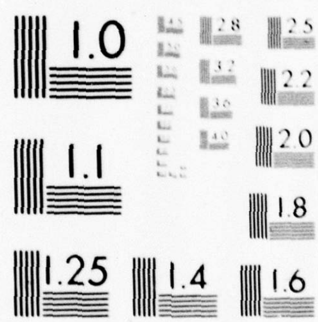

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963-A

LEVEL II

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Research and Development Technical Report

ECOM- 76-0175-F

AD A056286

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ELECTRET NOISE-CANCELLING MICROPHONE

Donald W. Mackiernan
Alan P. Woodard
JMR SYSTEMS CORPORATION
168 Lawrence Road
Salem, New Hampshire 03079

April 1978

Final Report for Period 28 July 1976 to 28 December 1977

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Electret Microphone with Associated Preamplifier
Linear Noise-Cancelling Microphone
Capacitor First Order Gradient Microphone

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This document covers the technical details of advanced development work performed to adapt the electret principle for the purpose of improving noise-cancelling microphones for military use. A major objective was to achieve a flat frequency response over a greater bandwidth and noise cancellation characteristics extending to a higher frequency cut-off point than previously possible with dynamic units.

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DEVELOPMENT OF A LINEAR NOISE-
CANCELLING ELECTRET MICROPHONE

1. Introduction

The pursuit of this development program was to design and evaluate a linear noise-cancelling electret microphone which possessed uniform frequency response over an extended range while maintaining good noise rejection at higher frequencies. In addition, the microphone was to be designed to meet military requirements for sensitivity, output impedance and environmental performance.

2. Microphone Design

The principle of operation employed in the design of such a microphone was that of a first order gradient electret capacitor device. The use of an electret design readily achieves a uniform response over a wide frequency range while allowing for excellent noise-cancelling characteristics to be obtained. The capacitor is formed by spacing a thin metallized foil away from a stationary electrode. The foil responds to the sound pressure across it and therefore yields an output equivalent to the pressure gradient. This foil is then the active diaphragm of the microphone assembly and selection of an ultra thin material yields a low mass and provides for a high frequency of resonance. The result is a design of extreme ruggedness with a smooth frequency response characteristic. Bonded to the stationary electrode is a charged electret element which acts as a source of bias for the capacitor. Together;

the active diaphragm, the electret, and the stationary electrode form a capacitive element capable of generating an electrical output which represents the acoustical input.

The approach employed in the JMR design was to contain the active capacitor element in a capsule and to package the amplifier in a separate shield can. This allowed for a capsule of minimal thickness to be designed yielding a very small effective length between front and rear ports without sacrificing symmetry with respect to polar response. A small effective length provides for a high frequency of crossover between the near and far field responses. An illustration of capsule assembly is shown in Figure 1.

In order to provide environmental protection to the electret capacitor element, both front and rear ports had to be treated in such a way as to appear open to the acoustic signal and closed to environmental elements. This was accomplished via separate means for each port. The rear port was sealed using a tensionless outer protective diaphragm which was metallized and electrically connected to the capsule housing. This sufficed to seal the rear port from environmental elements, as well as act as a shield to electromagnetic interference. The front port however was treated differently. A stainless steel screen was employed for protection since it was acoustically more transparent than an outer protective diaphragm. The effectiveness of an outer diaphragm on a

ELECTRET CAPSULE ASSEMBLY

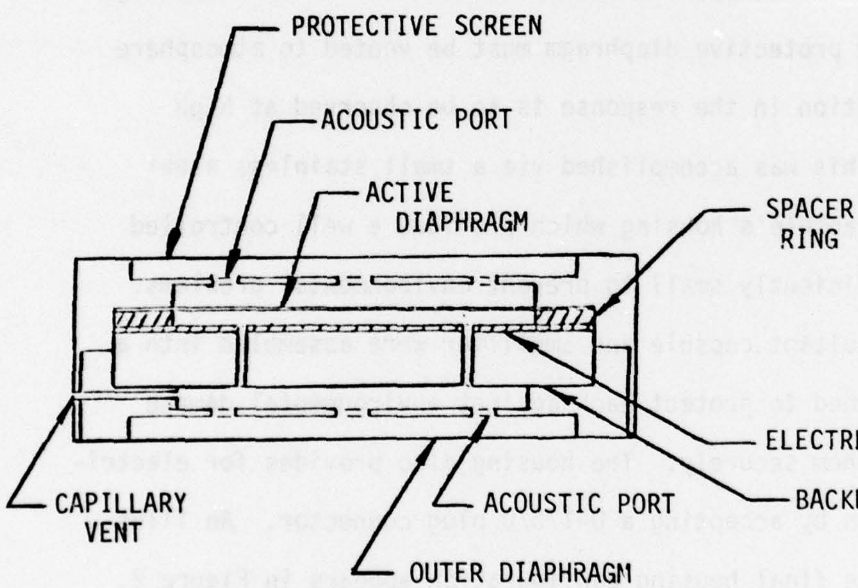
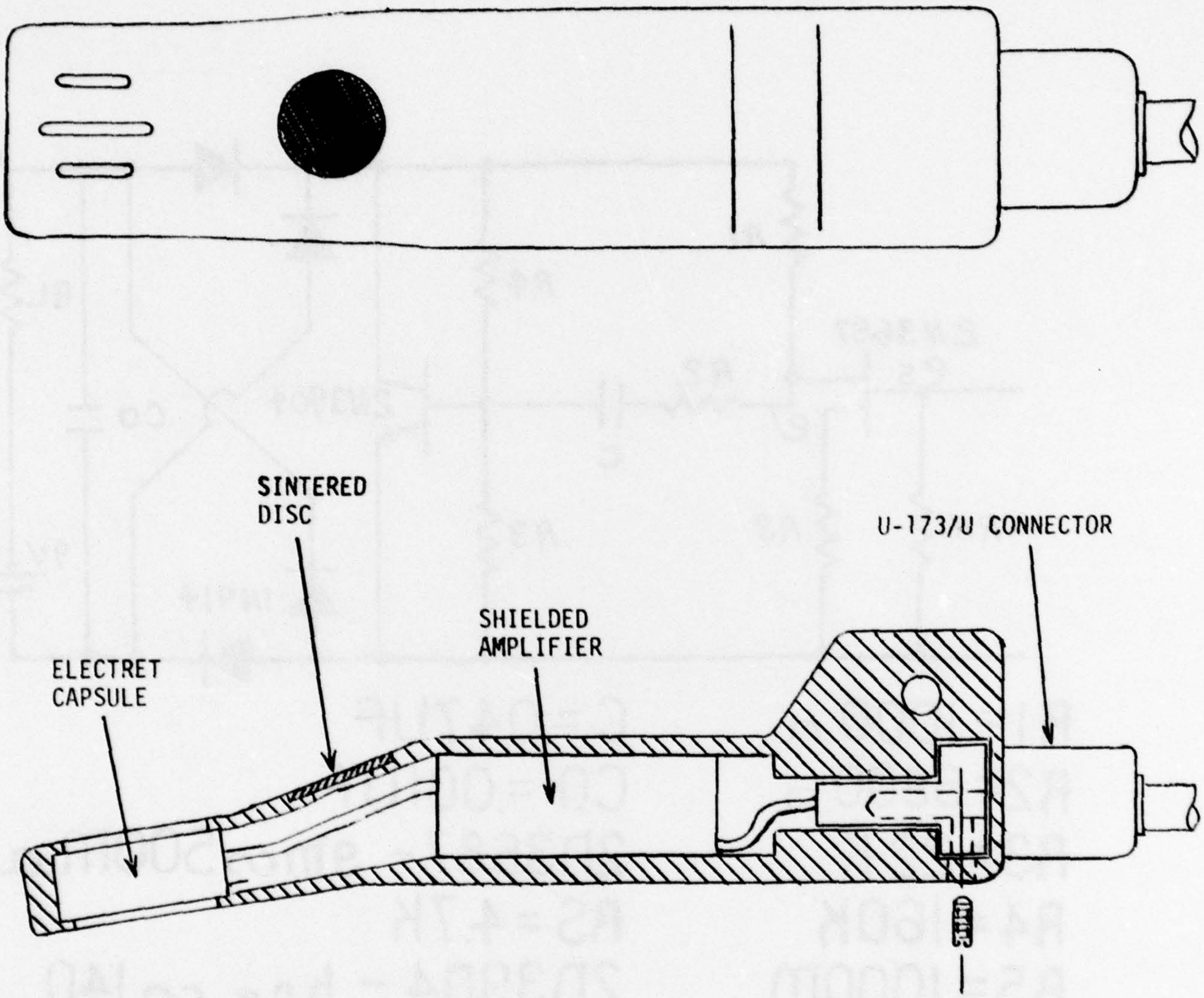


FIGURE 1

front port is greatly diminished since the coupling between it and the active diaphragm is so great that aberations in the response are observed to result when it is employed. The use of a stainless steel wire mesh screen which was treated with an antiwetting agent was found to provide sufficient protection for all environmental tests. Care was exercised in the selection of the pore size of the wire mesh screen and the tension of the rear outer diaphragm to insure symmetrical polar response of the final capsule. The rear air volume between the active diaphragm and the outer protective diaphragm must be vented to atmosphere if no degradation in the response is to be observed at high altitudes. This was accomplished via a small stainless steel tube in the capsule's housing which provided a well controlled air leak sufficiently small to prevent environmental problems.

The resultant capsule and amplifier were assembled into a housing designed to protect each against environmental damage and contain them securely. The housing also provides for electrical connection by accepting a U-173/U plug connector. An illustration of the final housing configuration appears in Figure 2.

Since the capsule is vented through its air leak tube into the housing, the housing is ported to the outside through a sintered disc. This disc provides air pressure equalization while preventing dirt and moisture entry.

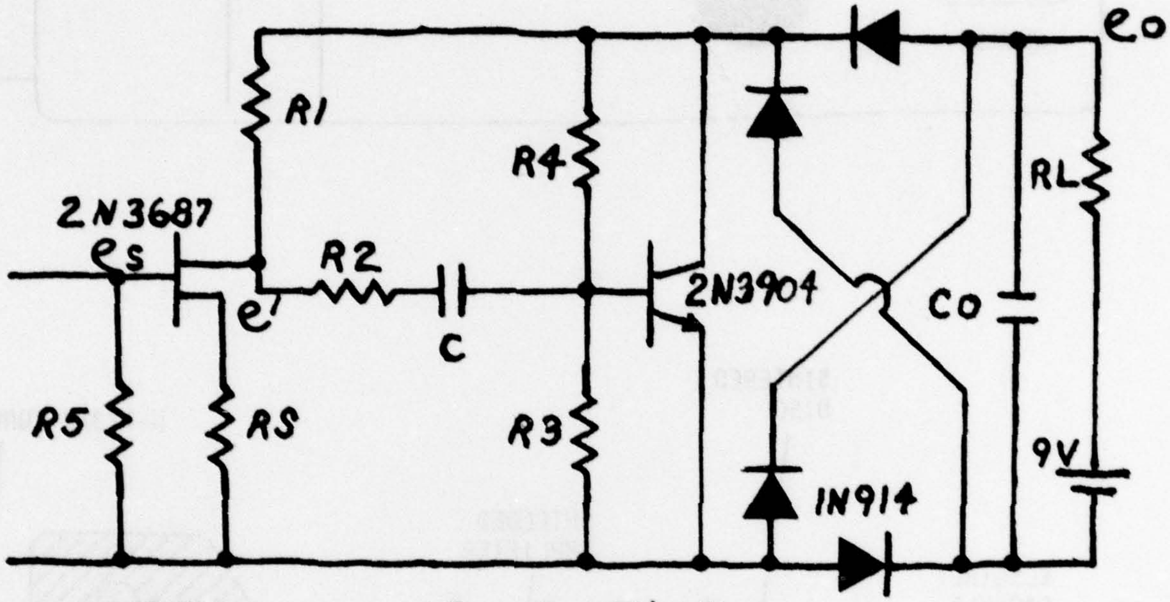


MICROPHONE HOUSING DETAIL

FIGURE 2

3. <u>Microphone Electronics</u>

The complete electronic circuit of the microphone system is shown below in Figure 3.



R1 = 1000 Ω
R2 = 6800 Ω
R3 = 22 K
R4 = 160 K
R5 = 1000 M
RL = 150 Ω
ZD = 39 Ω / DIODE

C = .047 UF
CO = .001 UF
2N3687 - gm ∽ 500 m Ω
RS = 4.7 K
2N3904 - h_{fe} ∽ 140
hie 1400

FIGURE 3

AMPLIFIER CIRCUIT

The microphone capsule has a design center sensitivity of -40dB re 1V/28 dynes/cm^2 when measured conventionally at the FET source (e' above). Since the FET follower has a loss of 3dB, the sensitivity at the FET gate (es) is -37dB re 1V/28 dynes/cm^2 (103dB SPL). The specification requires an over-all sensitivity of -60dB re 1V/28 dynes/cm^2, therefore the gain of the electronics must be -23dB when measured from es to eo above, i.e.,

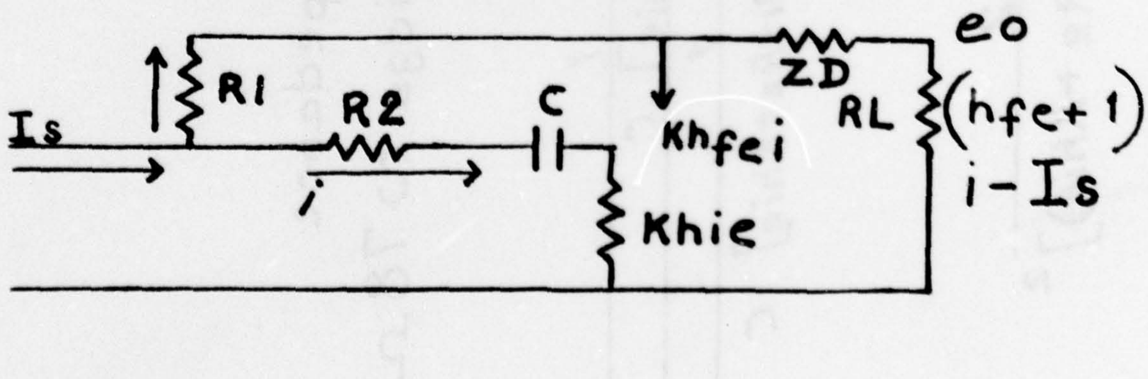
$$G = \frac{eo}{es} = .071 \ (-23DB)$$

In the above circuit R_4, in conjunction with R_3, set the static bias current of the transistor at approximately 3 ma, CO is an RF by-pass for EMI purposes. The effect of both of these components is negligible from a dynamic analysis viewpoint. Since $R_L \ll$ hoe and the gain is less than unity, the transistor parameters, hoe and hre may be neglected.

For analysis purposes, it is best to view the FET as a constant current source (Is) equal to $gm\,es/1 + gm\,Rs$.

i.e. $$I_s = \frac{gm\,es}{1 + gm\,Rs}$$

The above comments lead to the equivalent circuit, Figure 4.



$$K = \frac{R_3}{R_3 + h_{ie}}$$

$$Kh_{ie} = \frac{R_3 h_{ie}}{R_3 + h_{ie}}$$

K = fraction of i in h_{ie}

$$I_s = \frac{g_m e_s}{1 + g_m R_S}$$

Z = dynamic impedance of diode bridge $\approx 78\,\Omega$

From Figure 3, the following may be derived:

$$G_{(s)} = \left(\frac{e_o}{e_s}\right)(s) = \frac{Kh_{fe} R_1 - [R_2 + Kh_{ie}]}{(Kh_{fe} + 1)(R_2 + Z_D) + R_1 + R_2 + Kh_{ie}} \left\{ \frac{S - \dfrac{1}{[Kh_{fe} R_1 - R_2 + Kh_{ie}]\, C}}{S + \dfrac{1}{[(Kh_{fe} + 1)(R_2 + Z_D) + R_1 + R_2 + Kh_{ie}]\, C}} \right\}$$

$$G = \frac{Kh_{fe} R_1 - [R_2 + Kh_{ie}]}{(Kh_{fe} + 1)(R_2 + Z_D) + R_1 + R_2 + Kh_{ie}} \qquad f > f_c$$

$$f_{c\,(3DB)} = \frac{1}{2\pi C} \sqrt{\frac{1}{[(Kh_{fe} + 1)(R_2 + Z_D) + Kh_{ie}]^2} - \frac{2}{[Kh_{fe} R_1 - (R_2 + Kh_{ie})]^2}}$$

$$Z_o = Z_D + \frac{R_1 + R_2 + Kh_{ie}}{1 + Kh_{fe}} \qquad f > f_{(3DB)}$$

Substituting the component values, the following result

$G \approx -23.1$ DB

$f_c \approx 74.6$ Hz Low frequency 3DB cut off

$Z_{out} \approx 146.7\,\Omega$

4. Performance Tests

The performance of each microphone constructed was tested using a B & K artificial voice with the unit under test mounted 1/4" away from and coaxially with the opening. Results of these tests indicated that the front port response was typically smooth with an output measured to be constant within 3dB over the frequency range of 200 to 6000 Hz. In addition, a rear port sensitivity at 1000 Hz was measured under the same conditions and compared to the front port sensitivity at that frequency to assure a symmetrical polar response. A far field response of two units was performed in an anechoic chamber at a distance of 6 feet to insure that the noise immunity characteristic of the design requirements were met as specified in the development contract. A curve of both tests on a typical unit is illustrated in Figure 5. Figure 6 illustrates the noise immunity characteristic of a typical microphone.

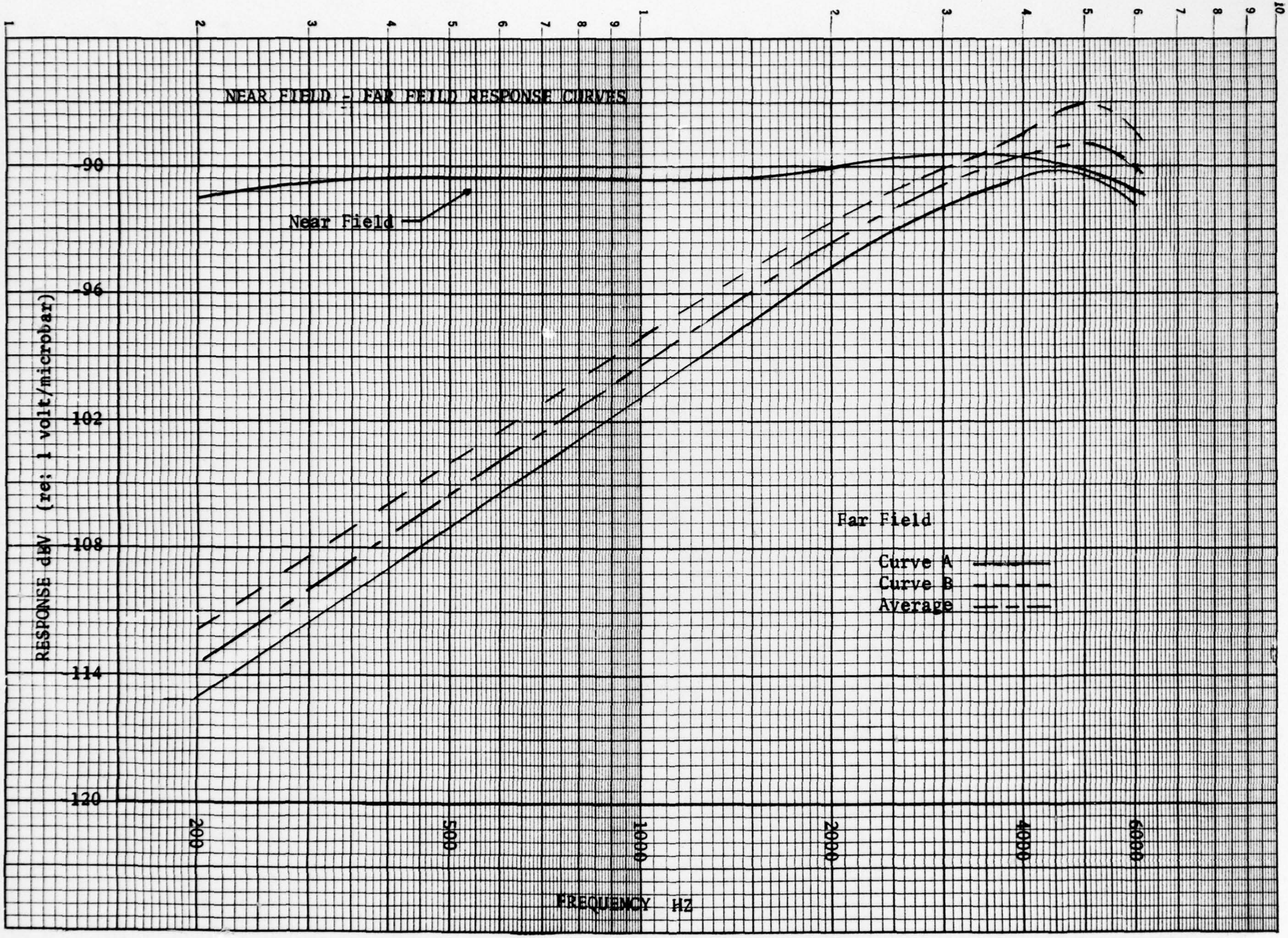
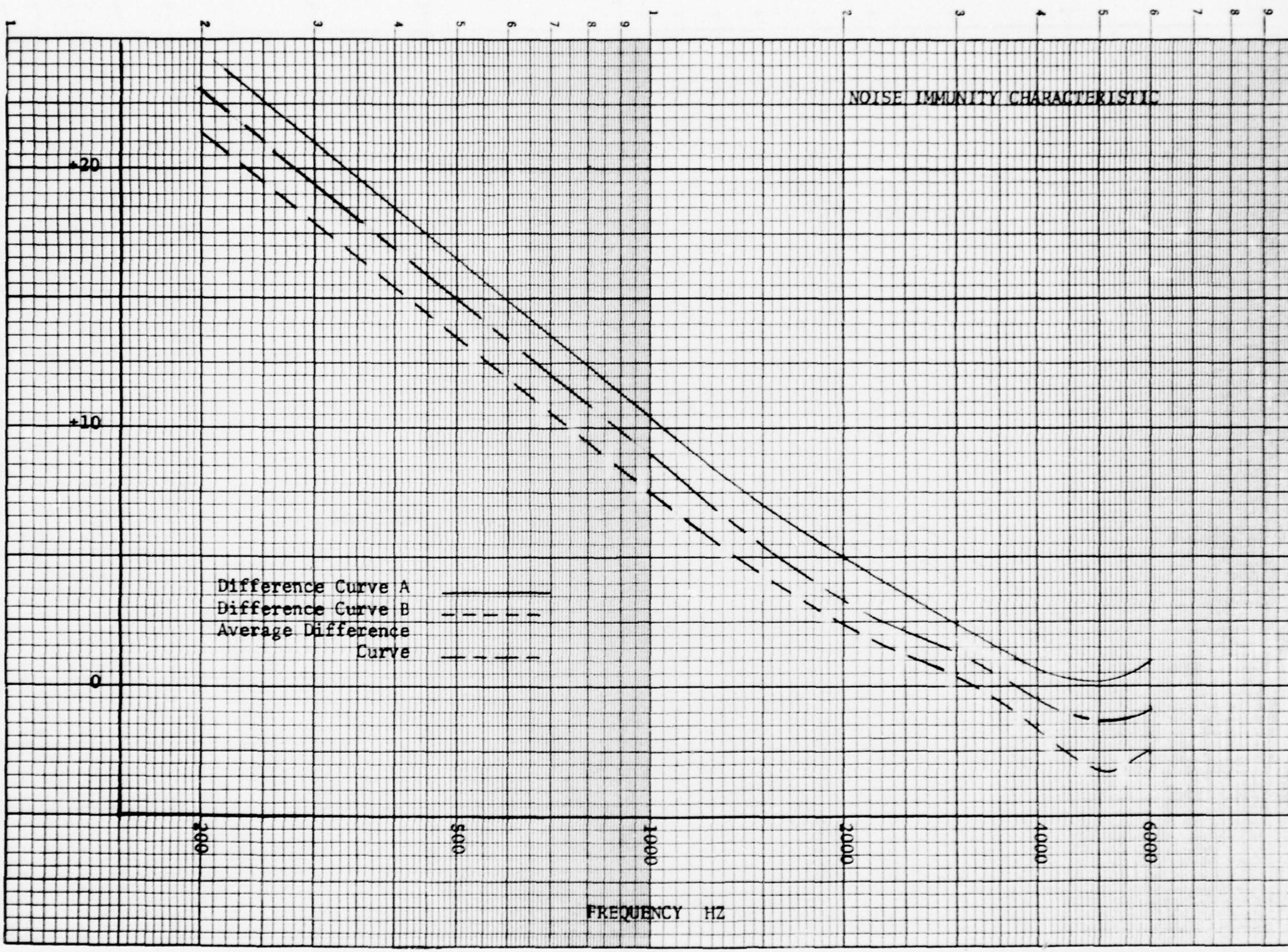

NEAR FIELD - FAR FEILD RESPONSE CURVES
Near Field
Far Field
Curve A
Curve B
Average
RESPONSE dBV (re: 1 volt/microbar)
-90
-96
102
108
114
120
200
500
1000
2000
4000
6000
FREQUENCY HZ

FIGURE 5



NOISE IMMUNITY CHARACTERISTIC
+20
+10
0
Difference Curve A
Difference Curve B
Average Difference
Curve
200
500
1000
2000
4000
6000
FREQUENCY HZ

FIGURE 6

In order to assure quality performance of the final microphone design, a test plan was prepared under the development contract. This test plan required specific testing to be accomplished and set limits of acceptance. Meeting this criteria was the goal throughout the entire program. Constant monitoring of performance criteria through the various stages of development made it possible to yield a resultant design that performed within acceptable limits.

In addition, environmental and EMI testing was accomplished as specified. The microphone design of this program was subjected to these tests and subsequently evaluated. Table 1 shows the schedule of environmental tests performed and the unit which was exposed to the specified test.

TABLE 1

Unit	Test Performed
C	Altitude
	Low Temperature - store, operate
	High Temperature - store, operate
	Vibration
	Shock
B	Salt Atmosphere
f	Immersion
	Dust
c'	Fungus
A	Humidity
-	Blast
-	EMI

The microphone, designed and evaluated by JMR, met all of the environmental test criteria, except for vibration. The cause for failure on the vibration test was a separation of the two housing halves. The material selected for use in the fabrication of the housing was Delrin which is difficult to bond since this material is of the fluorocarbon family. An attempt to design around this situation was employed by using mechanical means to secure the housing halves together, however, mechanical failure still resulted. Selection of a material such as ABS or a polycarbonate such as Lexan should overcome this problem in future units by allowing solvent cementing of the housing halves.

Two microphones were subjected to simulated gun blast tests at NOSC, San Diego. No change in output level, distortion or physical appearance was noted.

Frequency	Test Required	Field Strength
mHz	Field Strength V/m	At 1% Distortion V/m
.01 to 1.9	1.0	> 1.0
2.0 to 22.0	5.0	> 5.0
23.0	5.0	2.5
45.0 to 395.0	10.0	1.3 to 9.0

Since the microphone capsule and amplifier are 100% shielded (solid without breaks), it is likely that the EMI problem above 22 mHz is due to the unshielded output cable and lack of internal protection at the amplifier output terminals. Size constraints make the introduction of RF rejection filtering at that point extremely difficult.

5. Delivered Units

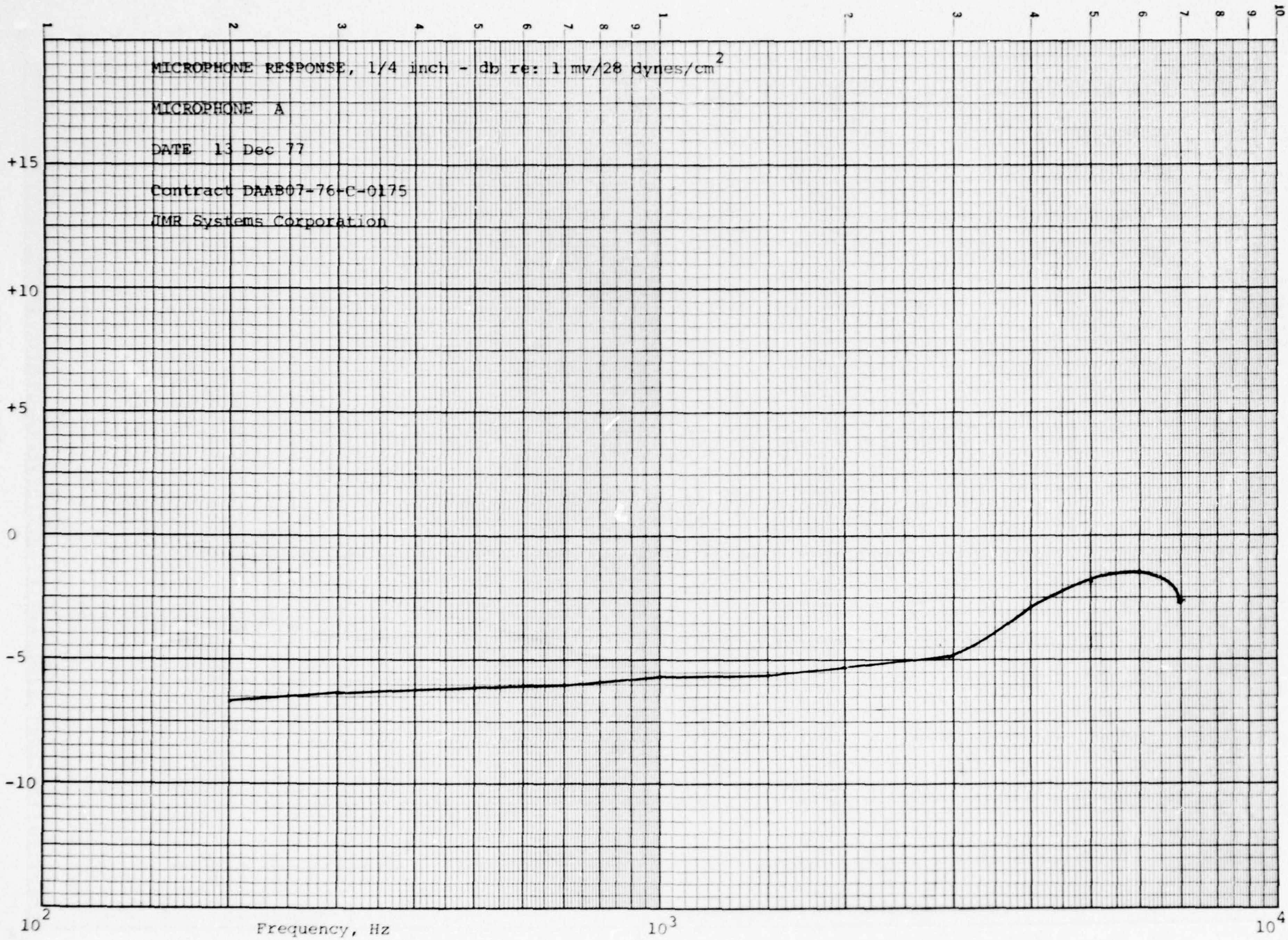
The 20 microphones delivered in satisfaction of the contract requirements included JMR capsules and amplifiers mounted in plastic housings. Each unit was delivered with boom assembly, Astrocom P/N 10346, and cable assembly, Astrocom P/N 22258.

Of the 20 units, 2 were the units subjected to simulated gun blast. Of the remaining 18, units A, B and C were environmental test units; D through S were new. Unit C had its housing (separated in vibration) repaired before delivery. Response curves, Figures 17 through 33, on these 18 units tend to show a resonant peak of 1 to 2dB between 4 and 5kHz. This is not strongly evident in all cases, and seems to be a result of minor variations in diaphragm tensioning. The curves do show that miniature electret elements are easily capable of ± 2dB from 200 to 6000kHz.

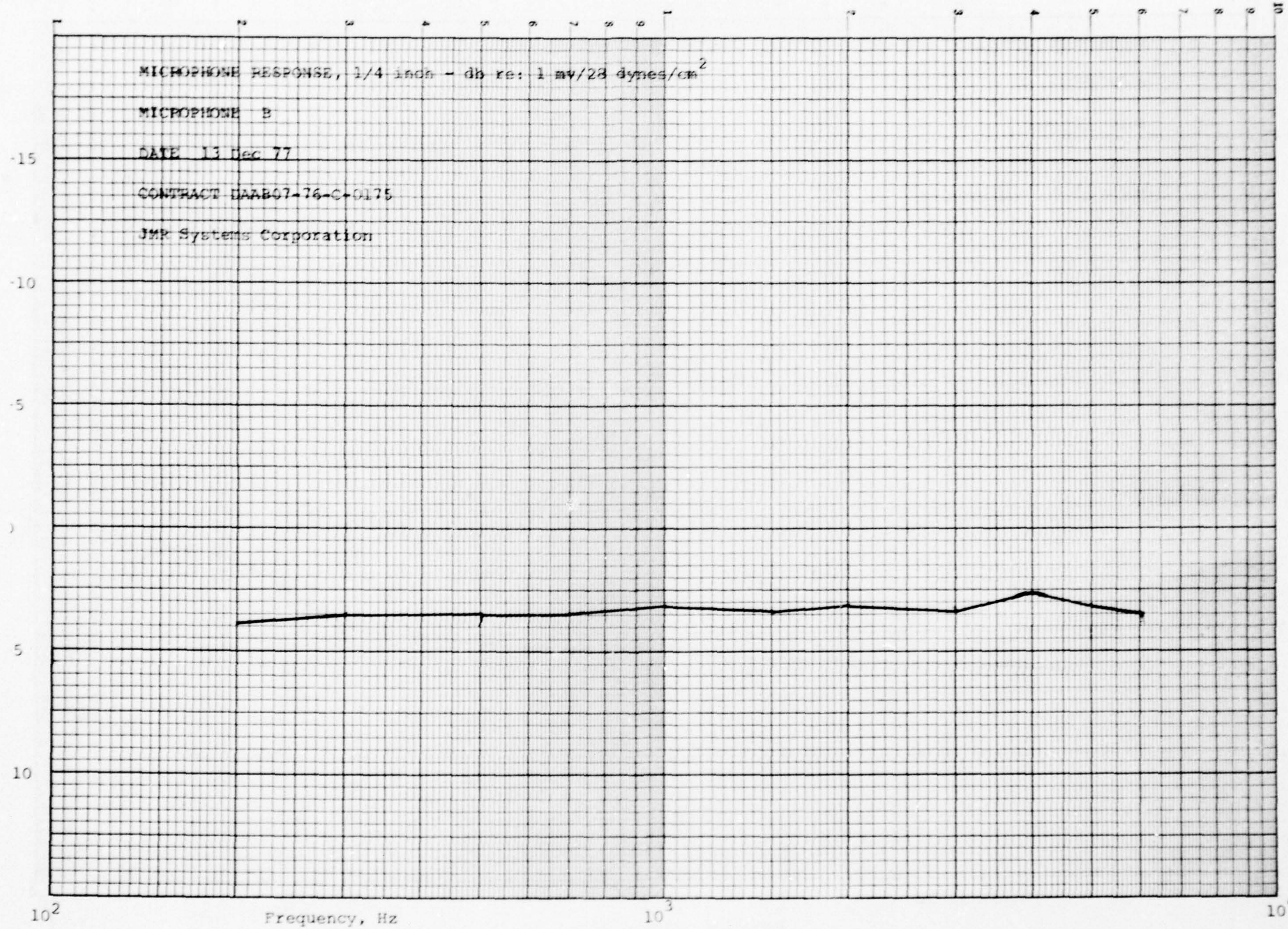
6. Conclusions

A) The noise cancelling performance of the microphone indicates far field crossover between 3 - 4,000Hz. The effective front to back spacing of the microphone is therefore approximately .6 inches with actual construction thickness being .19 inches. This indicates an improvement in noise cancelling performance compared to standard microphones now in the military inventory.

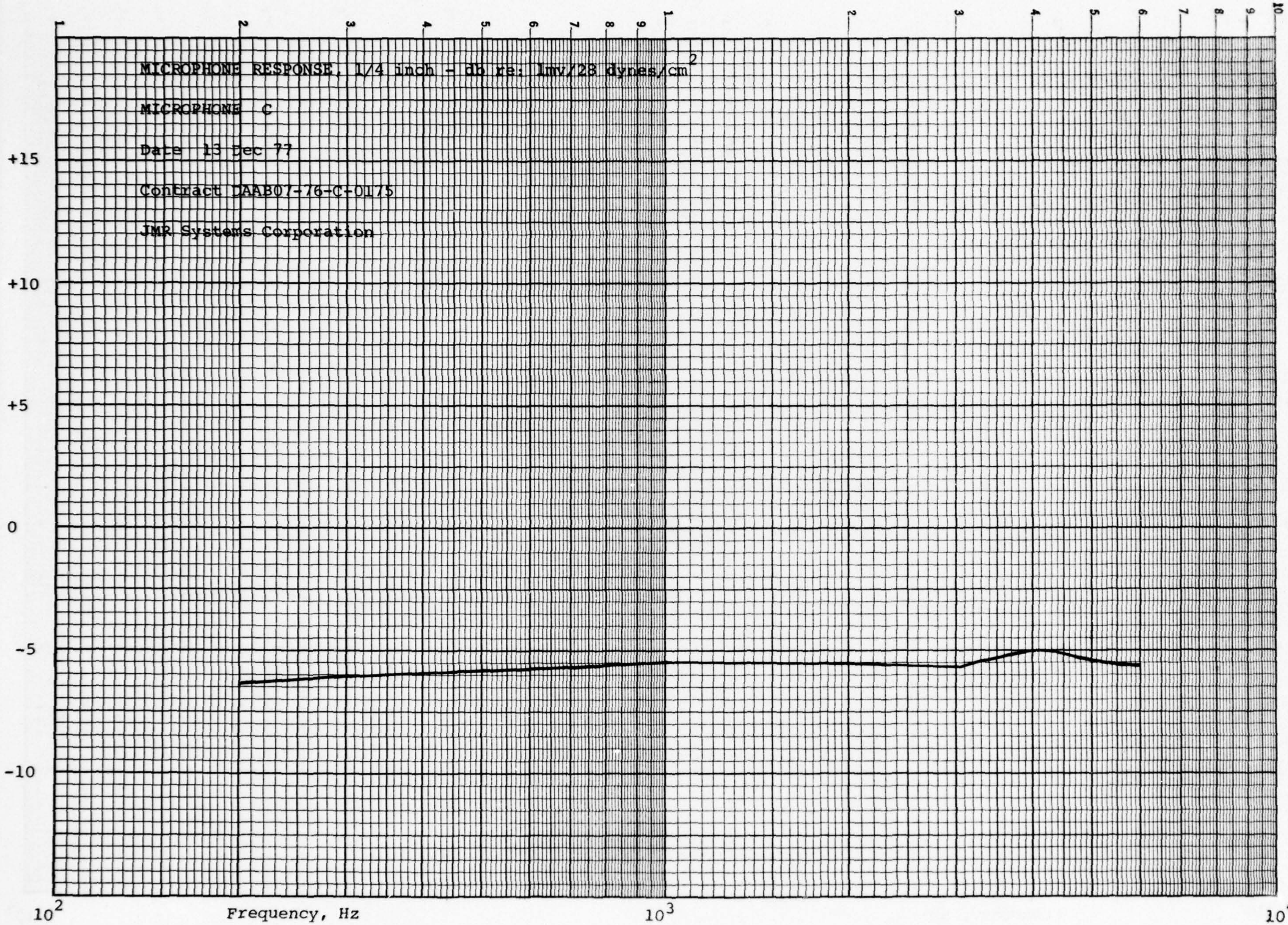
B) It is considered practical to specify microphone response within ± 2dB for volume production. All microphones delivered were within this performance, and although a number of microphones maintained performance within ± 1dB by hand selection and process control,



Page 17, Figure 17

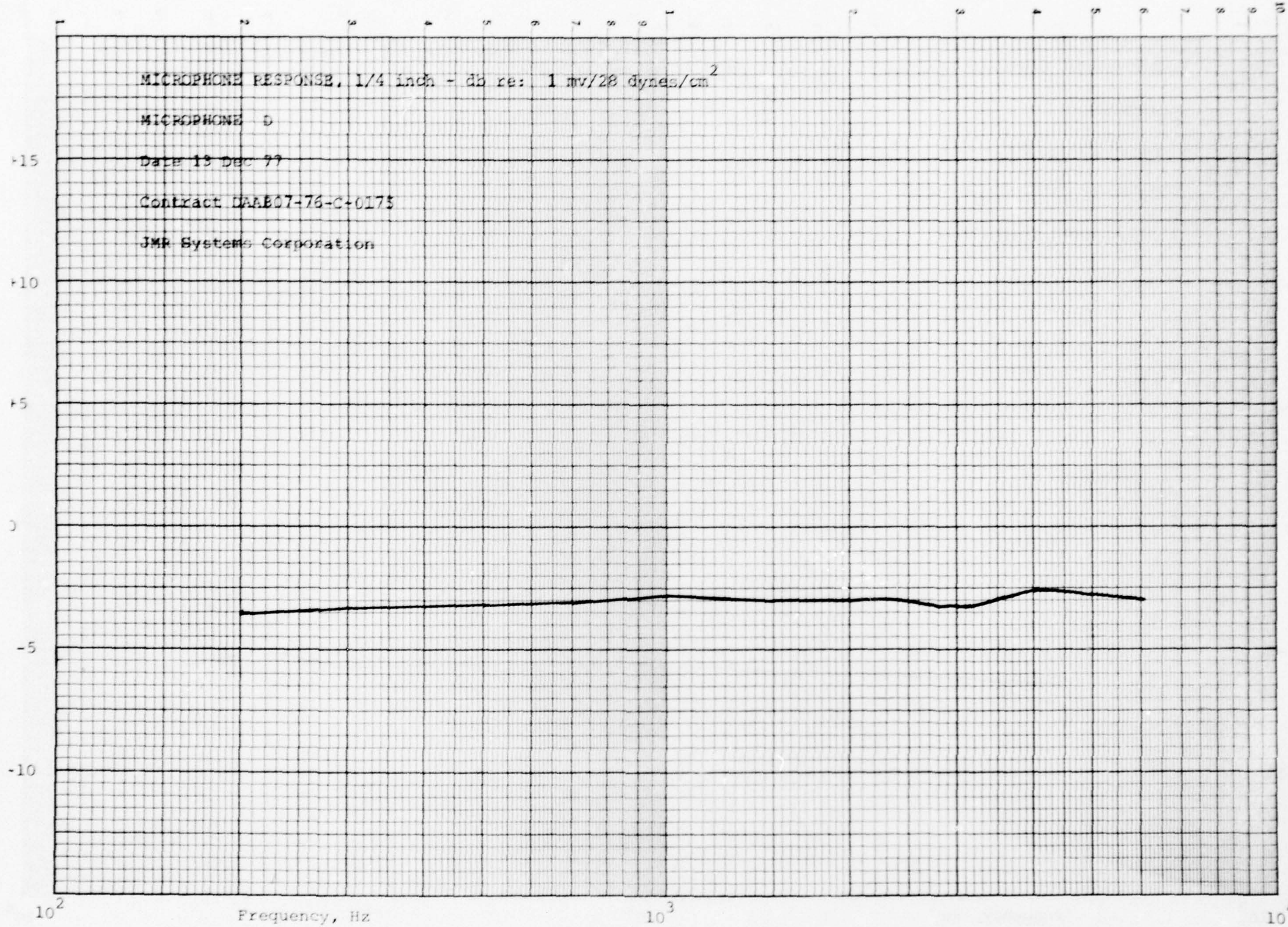


Page 18, Figure 18



MICROPHONE RESPONSE, 1/4 inch - db re: 1mv/28 dynes/cm²
MICROPHONE C
Date 13 Dec 77
Contract DAAB07-76-C-0175
JMR Systems Corporation
+15
+10
+5
0
-5
-10
10²
10³
10⁴
Frequency, Hz

 Figure 19



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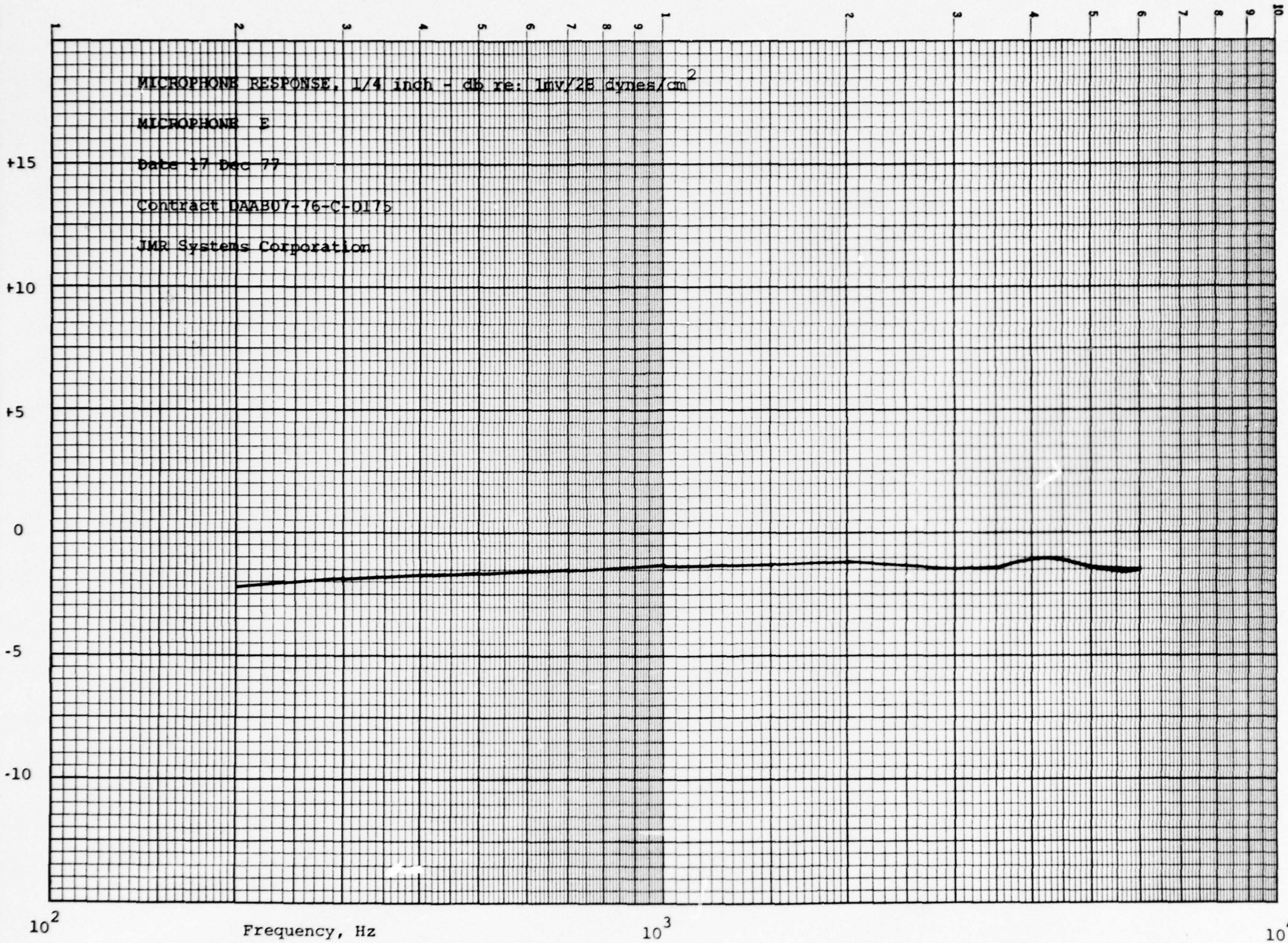

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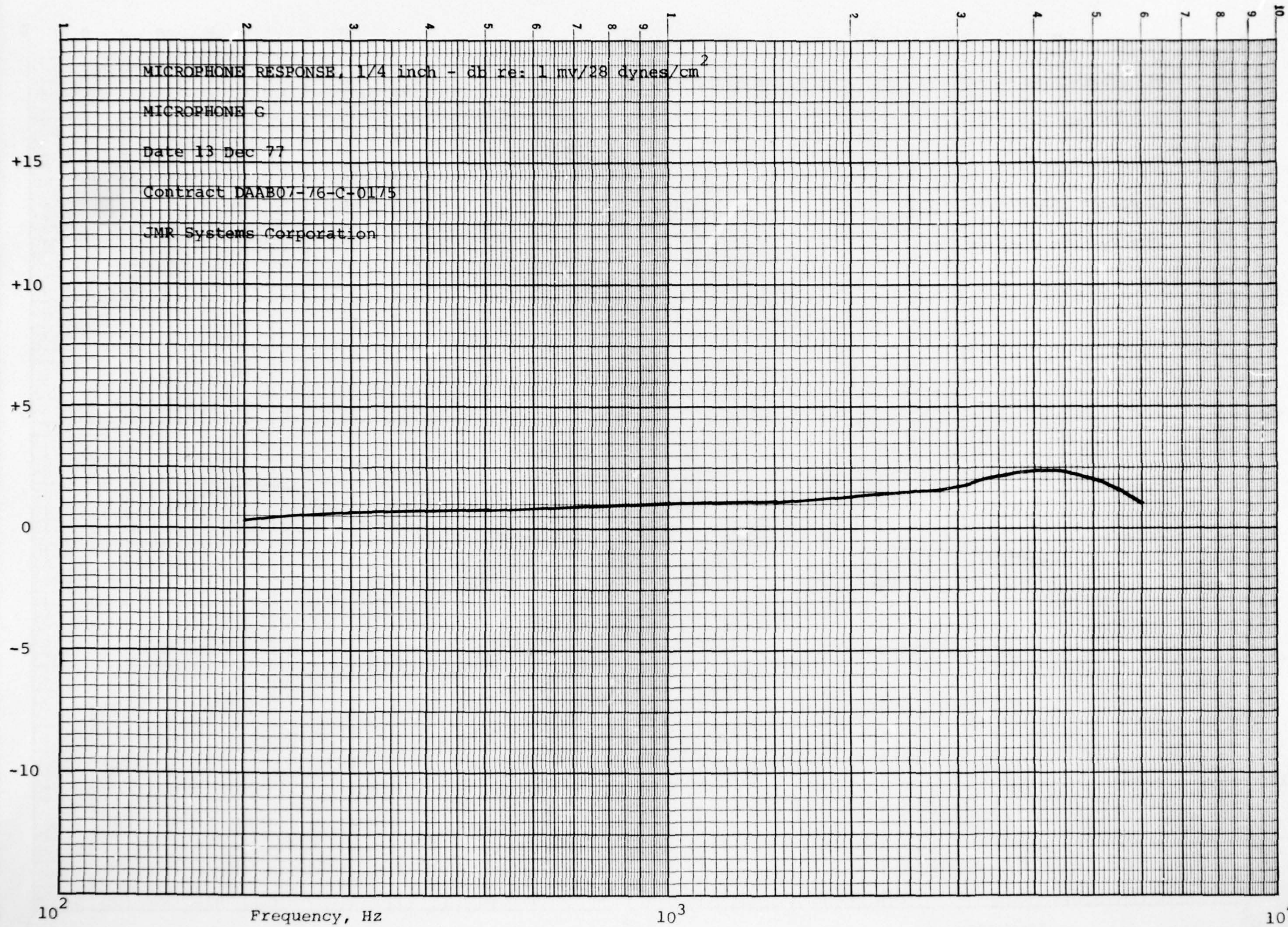

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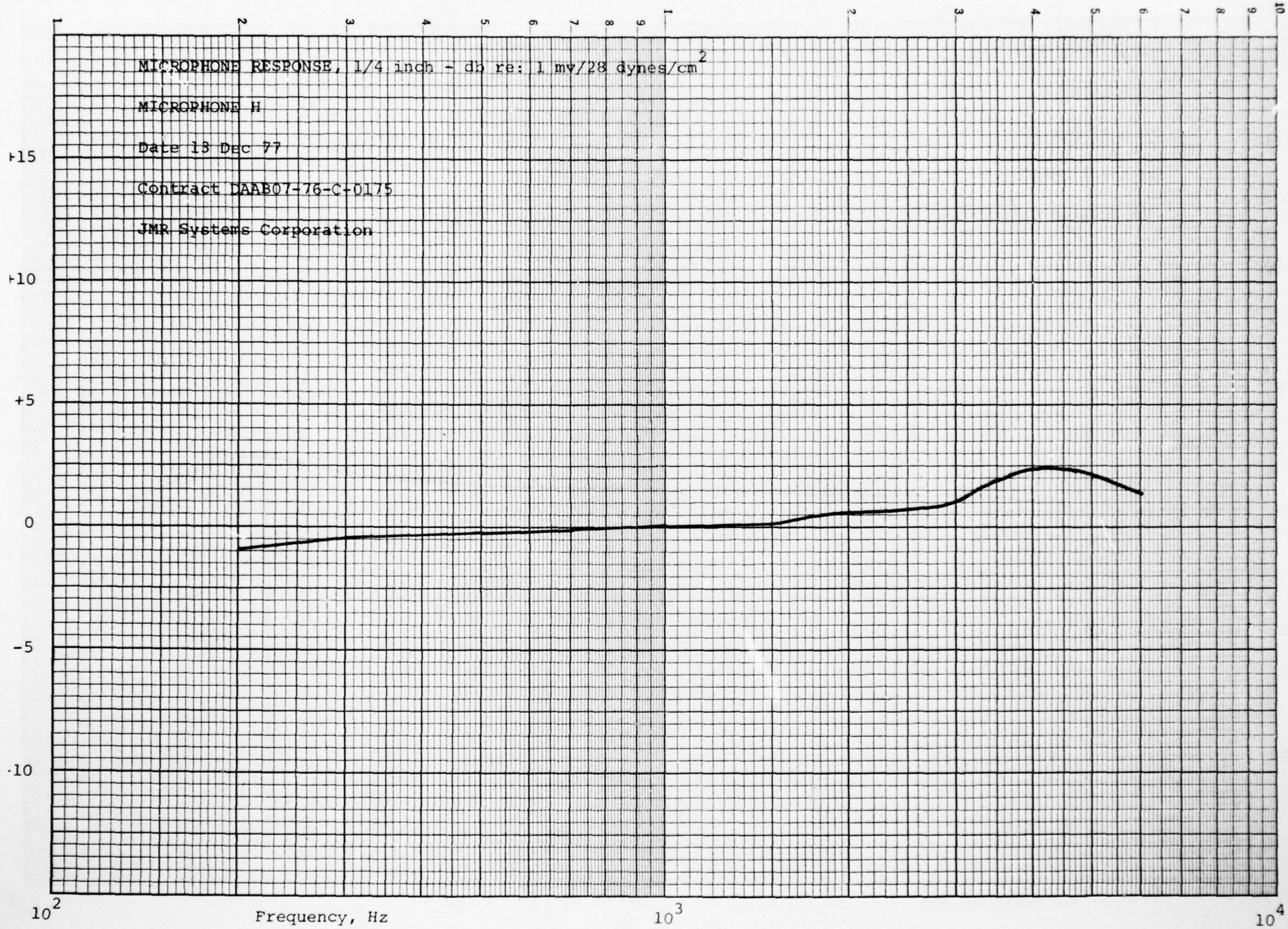
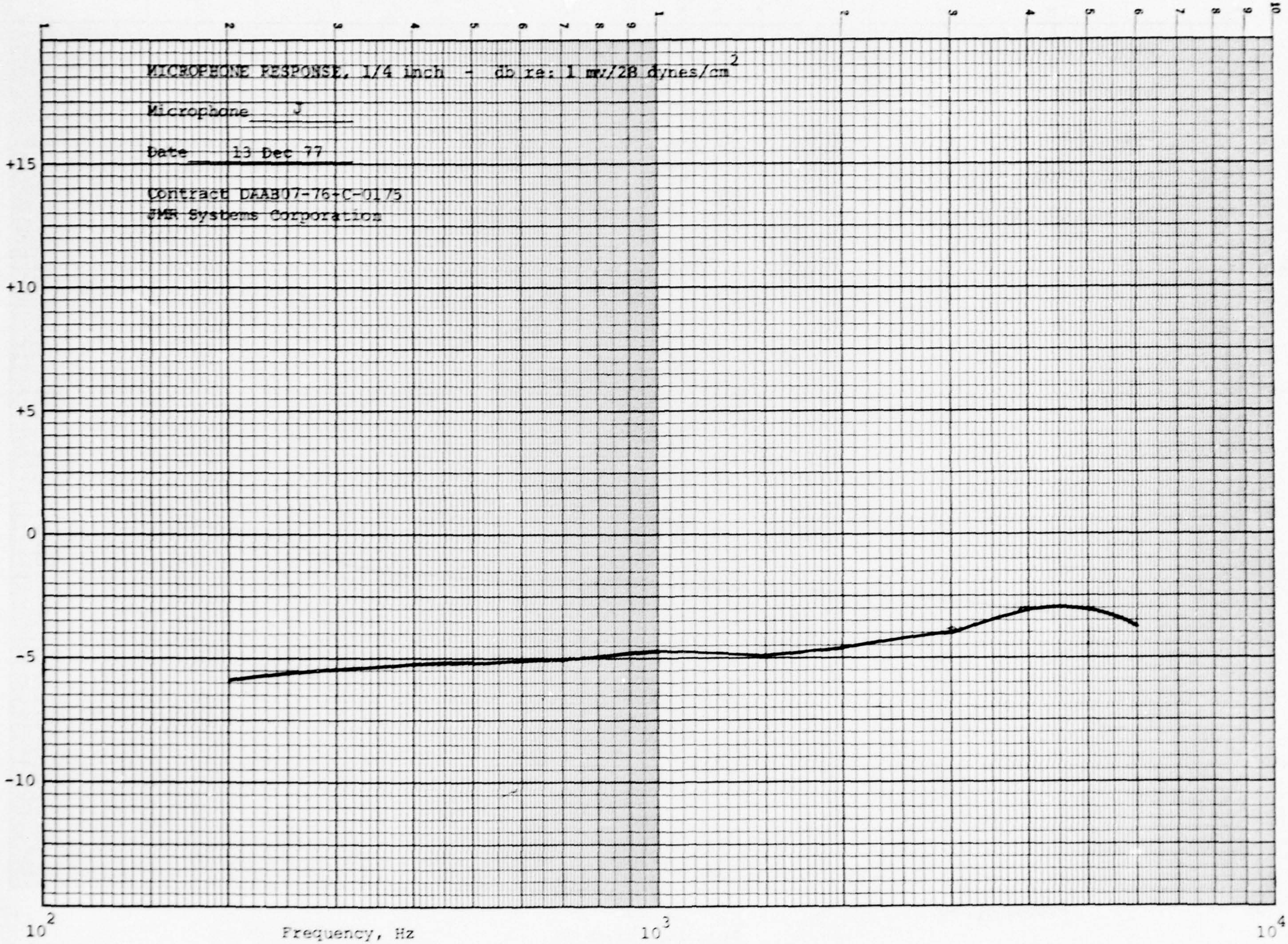


Page 24, Figure 24



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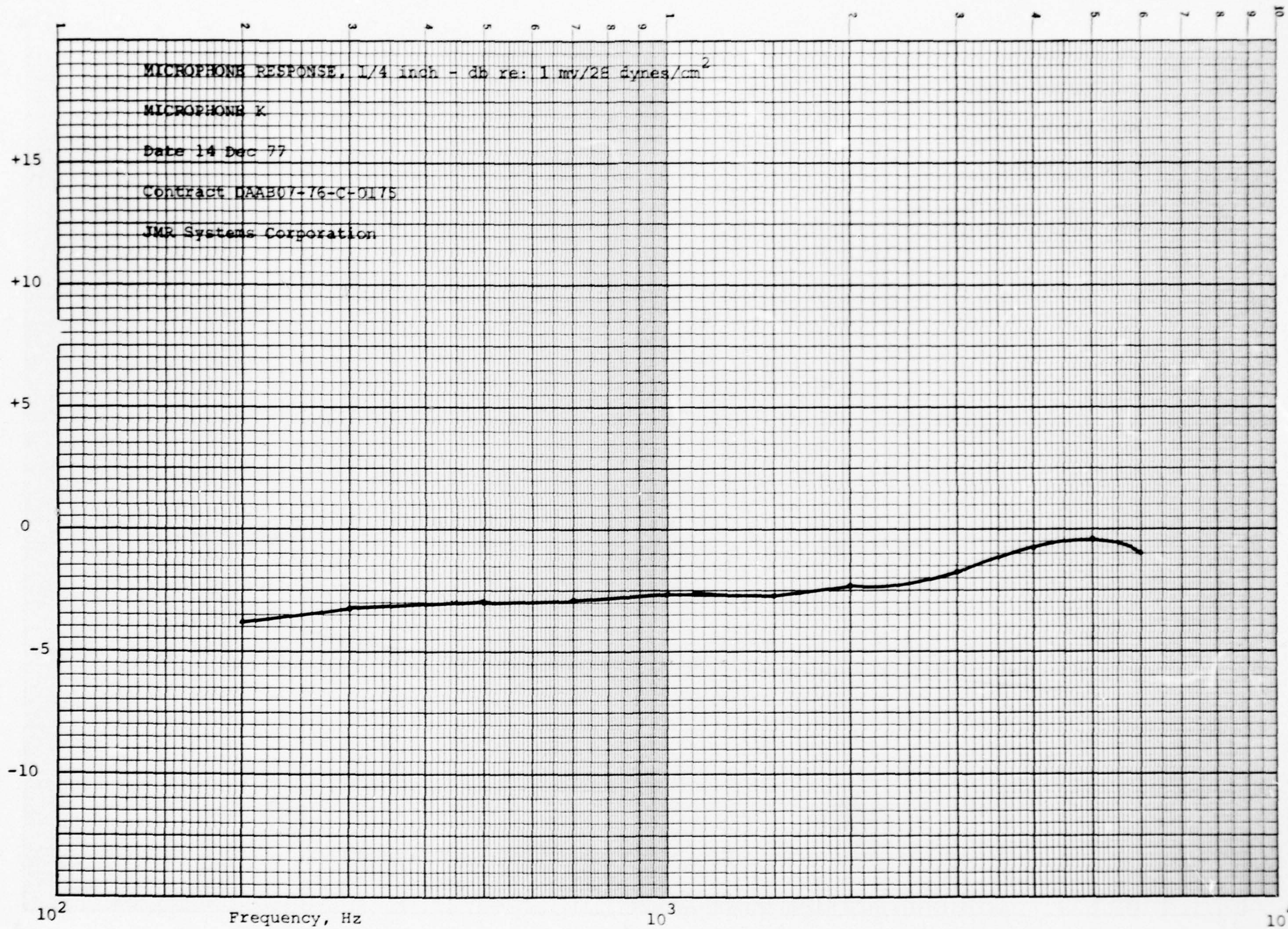

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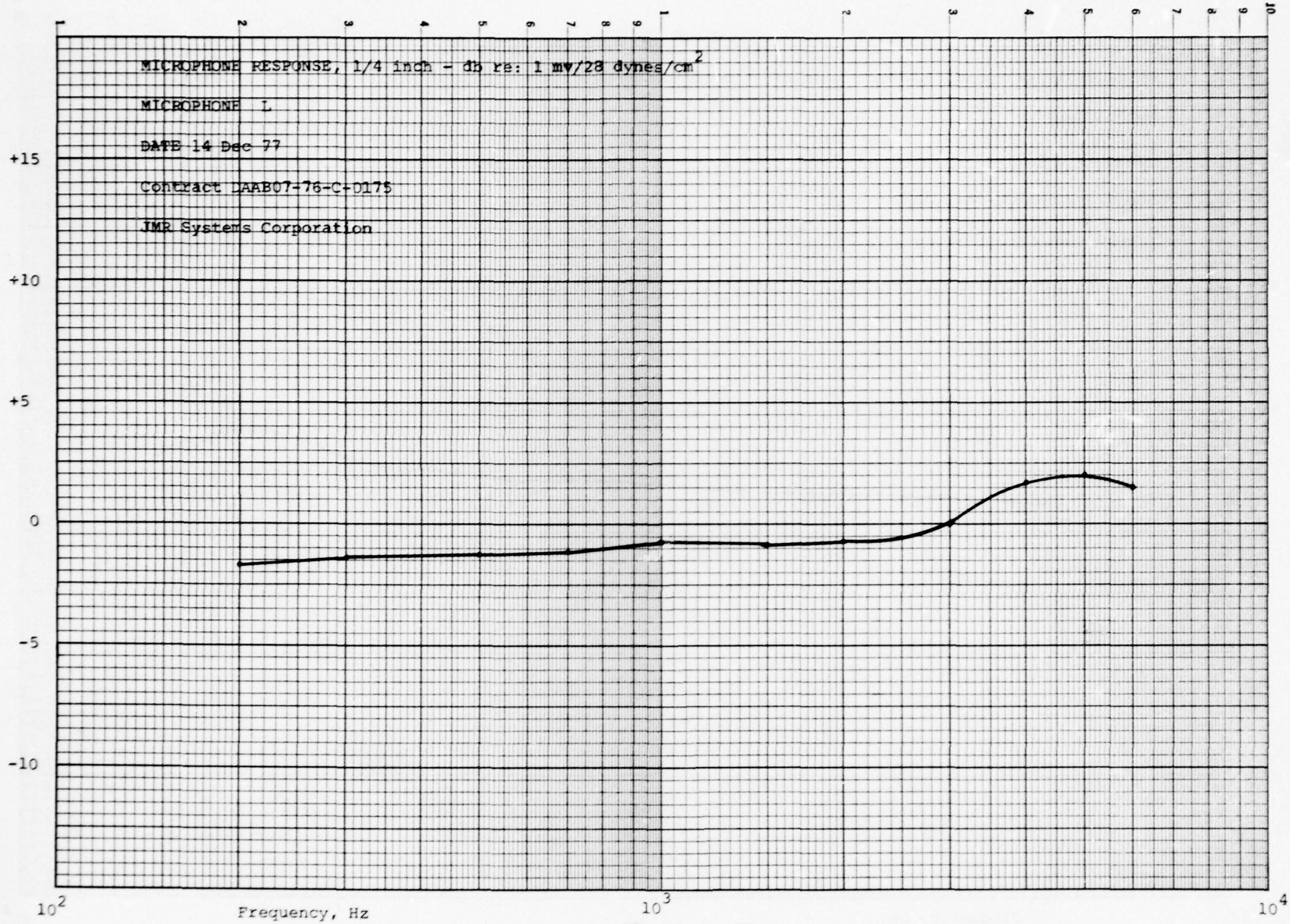

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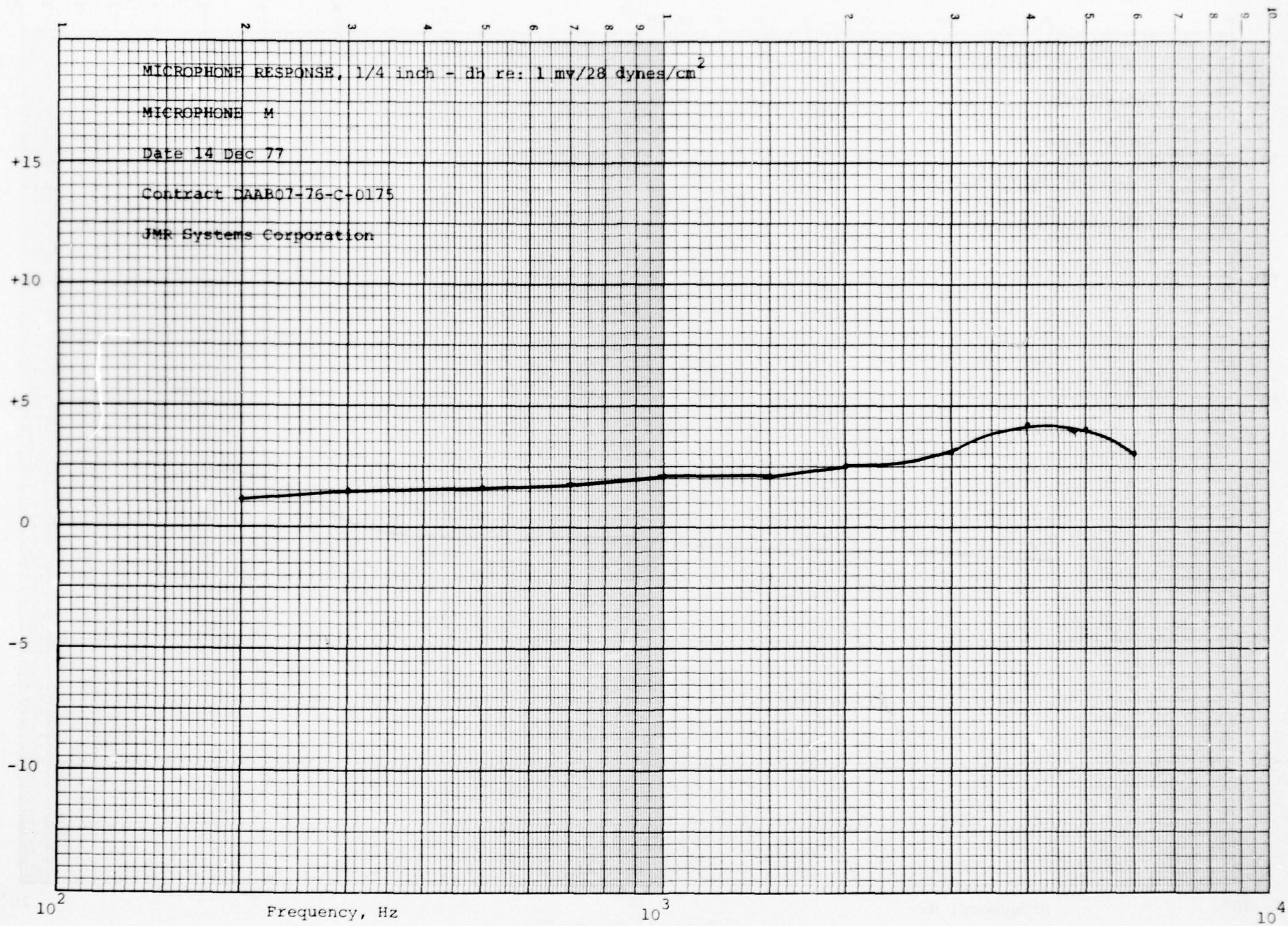
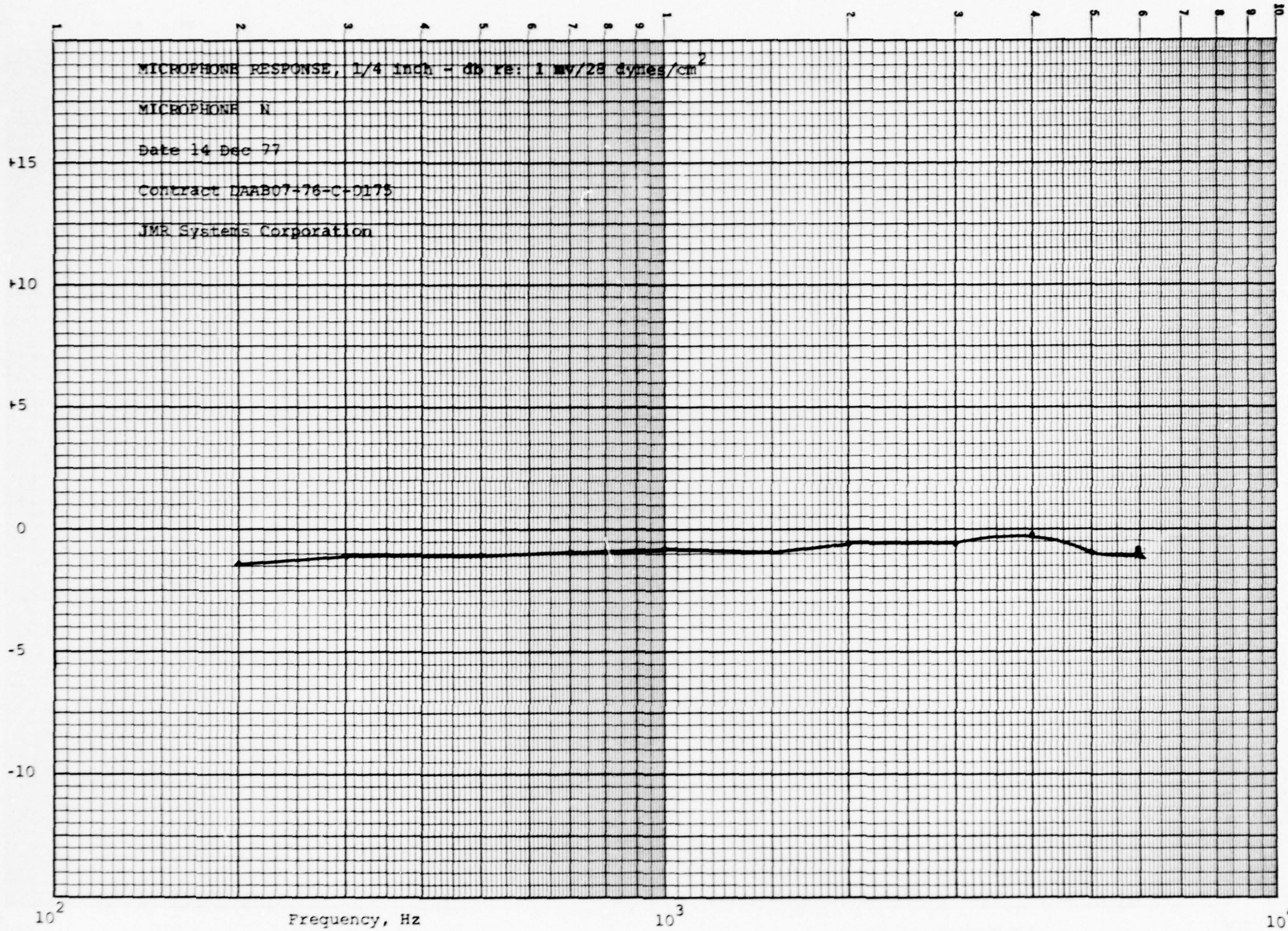
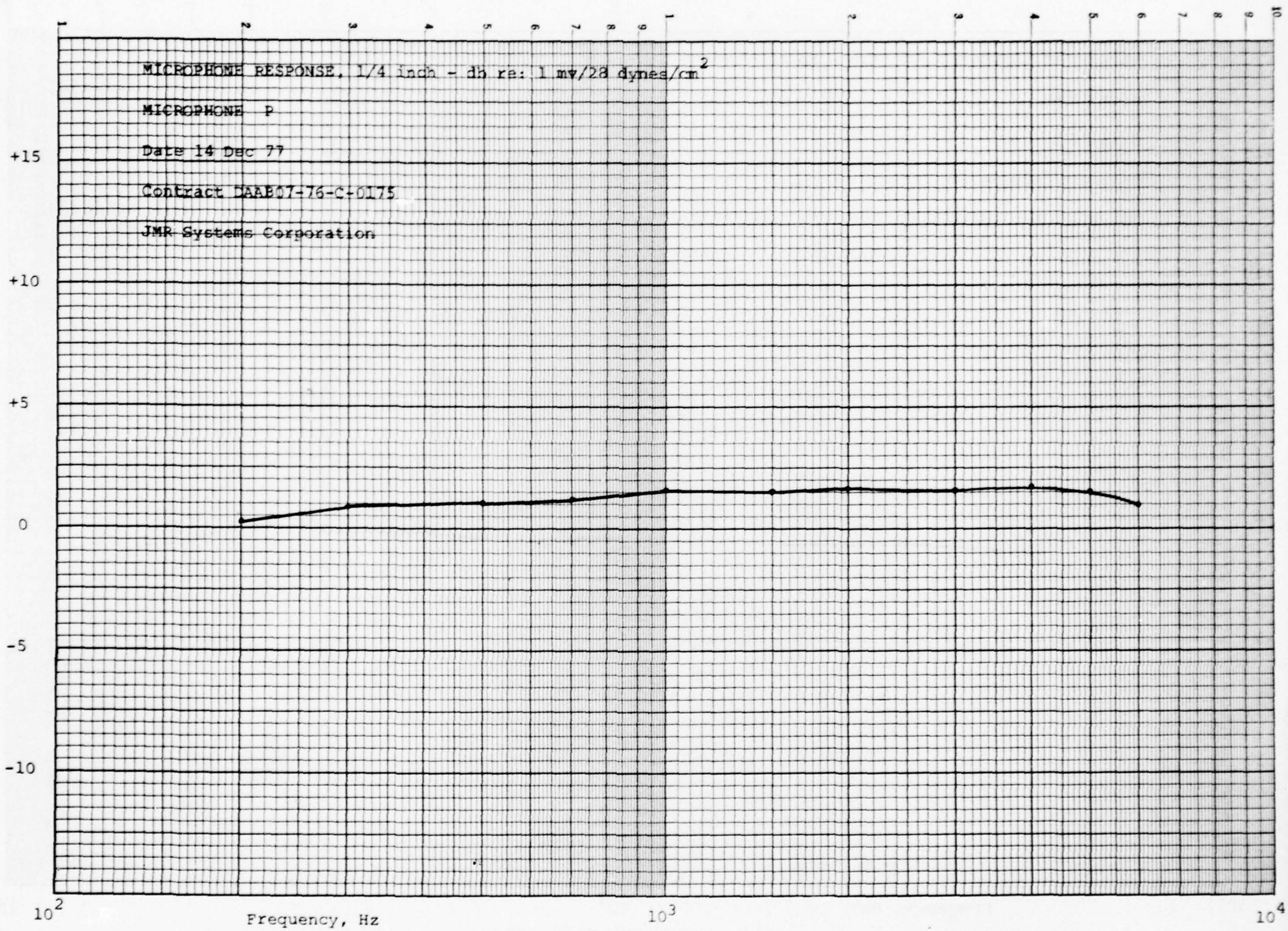


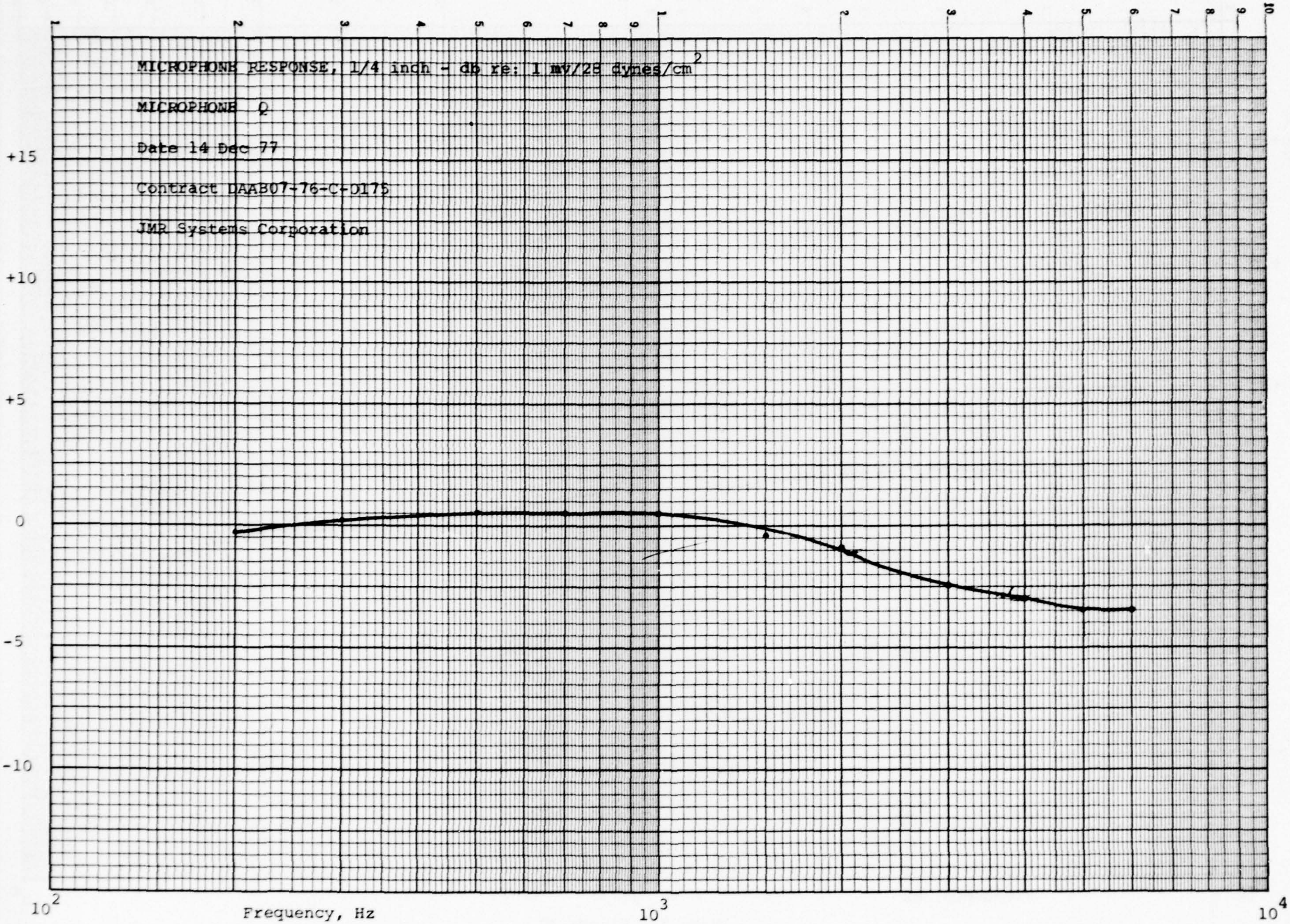
Page 28, Figure 28



Page 29, Figure 29



Page 30, Figure 30



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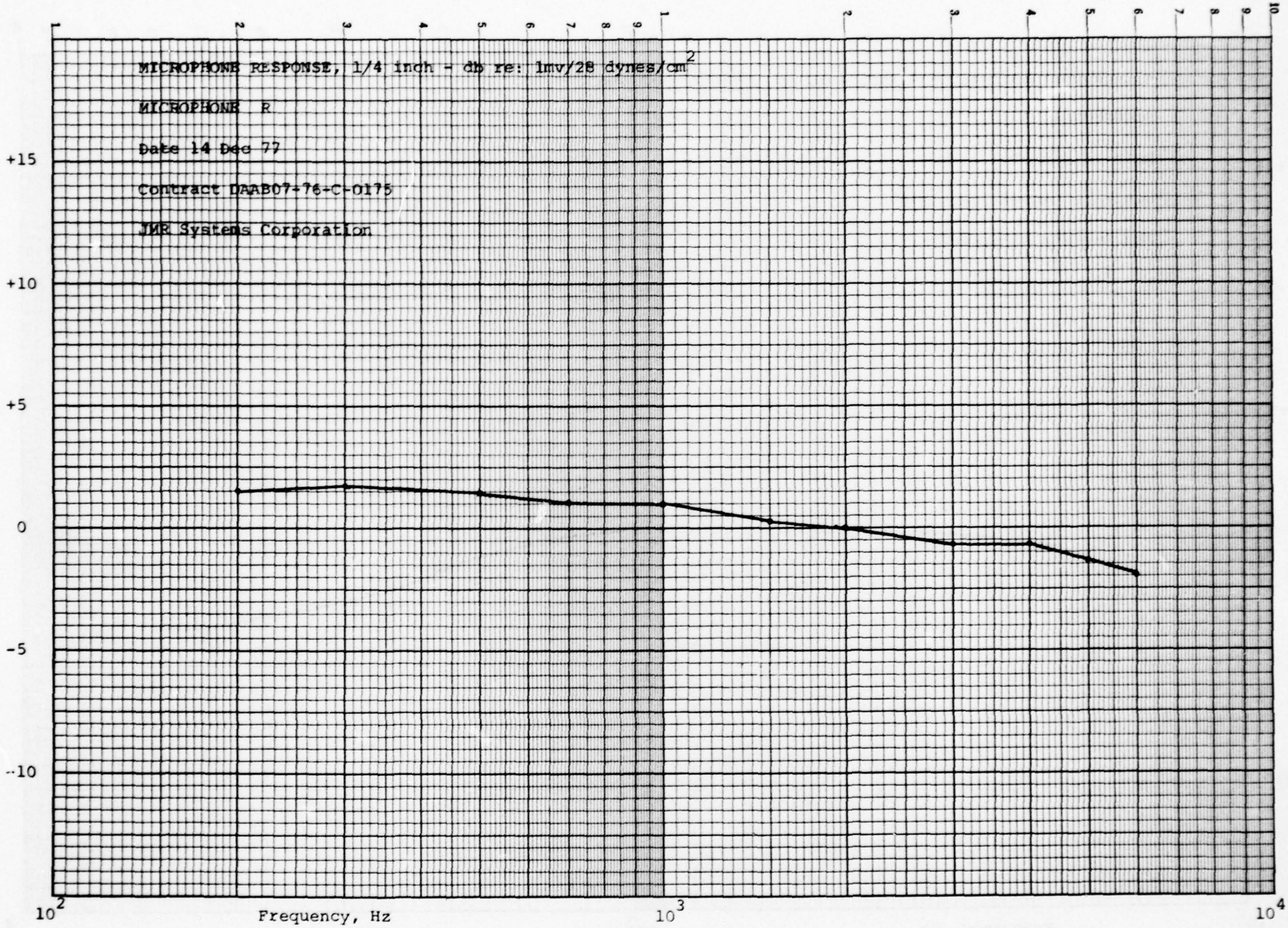
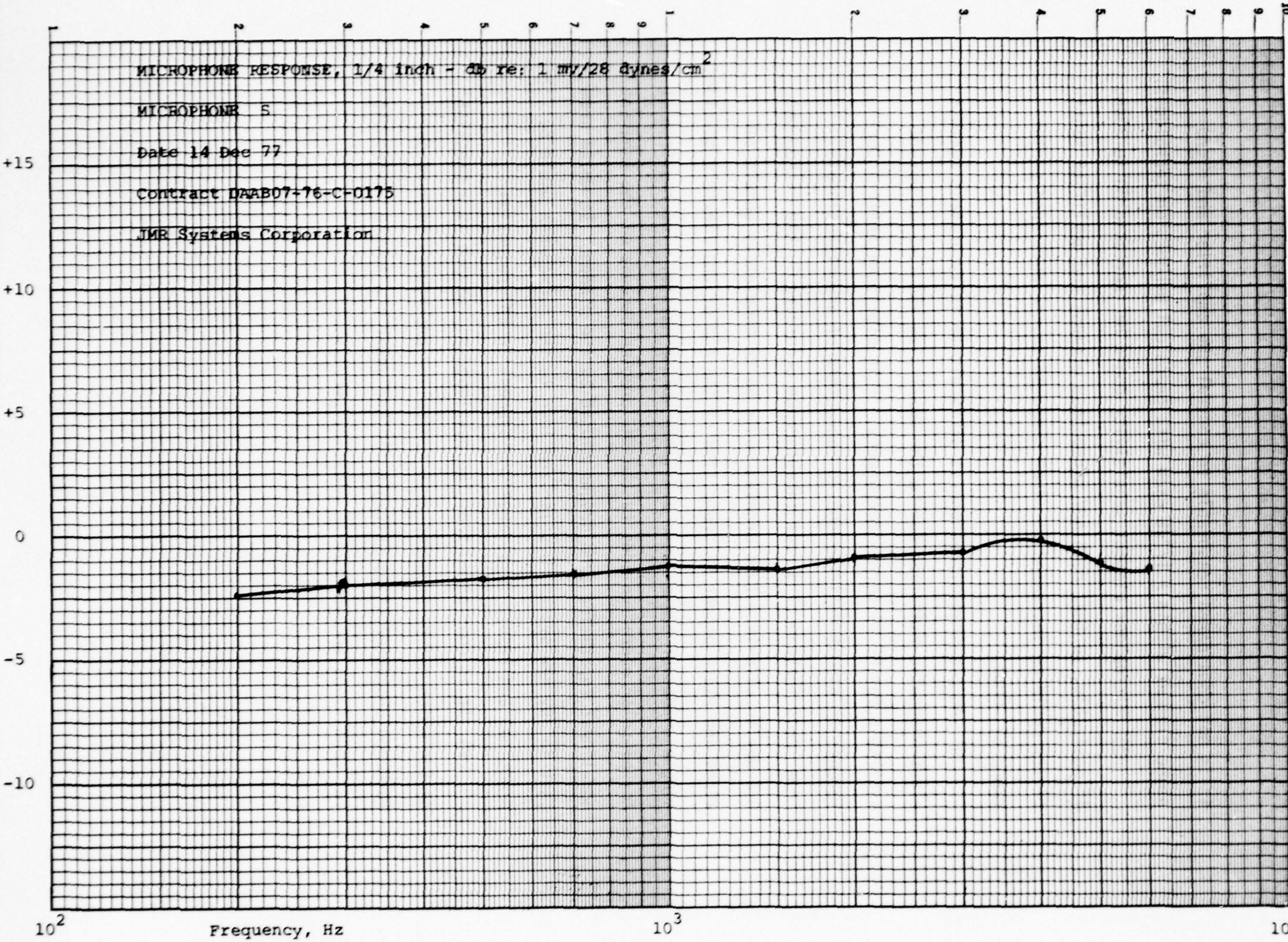


Page 32, Figure 32



Page 33, Figure 33

it is not considered reasonable to control the amplifier and microphone element within $\pm$ 1/2dB each with practical production techniques.

C) Microphone element sensitivity could be increased 20 to 30dB, if desirable, so that combined microphone element and amplifier sensitivity could be increased to -40dB compared to the delivered performance of -60dB.

D) An electret microphone is difficult to fully protect against electromagnetic radiation due to the small size and lack of volume available for RF filtering components. This electromagnetic interference is almost entirely due to conduction of unwanted signals from leads instead of direct interference occurring in the microphone. One way to alleviate this problem would be to completely shield the wires and place proper RF protection at the end of the flexible shielded single conductor cable where available volume exists. The requirement for bi-polar operation adds to the EMI problem because of the inherent non-linear separation from ground caused by the diodes. It would seem that in any new system, a polarized lead to the microphone would be practical and result in a large improvement in EMI rejection.

E) It is considered that the developed microphone is a practical design which can be produced with controlled procedures to have performance characteristics suitable for use under the severe environmental conditions encountered in military service.

APPENDIX A

ENVIRONMENTAL DATA

Test Report No. T-5762-11 No. of Pages 18

Report of Test on

MICROPHONES

ENVIRONMENTAL TESTS

for

JMR SYSTEMS

Associated Testing Laboratories, Inc.

Date December 12, 1977

	Prepared	Checked	Approved
By	R. Montvitt	R. Borghetti	H. Spector
Signed	R. Montvitt	R. Borghetti	H. Spector
Date	12/14/77	12-27-77	12/20/77

Administrative Data

1.0 Purpose of Test:

To determine the effects upon the submitted Microphones when subjected to the tests specified in this report.

2.0 Manufacturer: JMR Systems
168 Lawrence Street
Salem, New Hampshire 03079

3.0 Manufacturer's Type of Model No.: Unspecified

4.0 Drawing, Specification or Exhibit: MIL-STD-810C, MIL-STD-454C and written instructions from JMR Systems

5.0 Quantity of Items Tested: Six (6) S/N's G, F, H, I, J and F

6.0 Security Classifcation of Items: Unclassified

7.0 Date Test Completed: October 25, 1977

8.0 Test Conducted By: Associated Testing Laboratories, Inc.

9.0 Disposition of Specimens: Returned to JMR Systems

10.0 Abstract:

The submitted Microphones were subjected to environmental testing in accordance with the above specifications. The following table lists the tests each unit was subjected to and the results.

Report No. T-5762-11

10.0 Abstract: (continued)

Test	Unit (S/N) Tested	Date Completed	Results
Immersion	F	10-12-77	No leakage
Salt Fog	I	10-14-77	No corrosion noted
Sand and Dust	F	10-18-77	No damage noted
Fungus	C	10-19-77	No fungus growth noted
Vibration	J	10-20-77	No damage noted
Humidity	H	10-25-77	Unit delaminated on ends
Shock (Drop)	J	10-26-77	Unit delaminated on ends

Report No. T-5762-11

Associated Testing Laboratories, Inc.

Wayne, New Jersey 07470

Burlington, Massachusetts 01803

Report No. T-5762-11

LIST OF APPARATUS

ITEM	MANUFACTURER	MODEL NO.	ACCURACY	CALIBRATION DATE	CALIBRATION DUE
High-Low Temperature Humidity Chamber	Associated Testing Laboratories	LHHV-36-LC	±2°F	Provided by Item #6	
Electric Autoclave	D.A. Kodan Co.	608	±1div gauge	6-15-77	12-15-77
Strobscope	General Radio	1531-B	±1%	8-8-77	11-8-77
Counting Chamber	Spencer	C-5856	N/A	Before use	
International Clinical Centrifuge	International Equipment Co.	CL	N/A	Before use	
Thermocouple Bridge	Minneapolis-Honeywell	2714	±2°F	6-17-77	12-17-77
Salt Spray Chamber	Associated Testing Laboratories	MX-9216	±2°F	8-26-77	11-26-77
pH Meter	Coleman	Metrion IV 28C	±.05pH	7-21-77	10-21-77
Hydrometer	Scientific Glass Apparatus	H-7990	N/A	N/A	N/A

LIST OF APPARATUS (continued)

ITEM	MANUFACTURER	MODEL NO.	ACCURACY	CALIBRATION DATE	CALIBRATION DUE
Mercury Thermometer	Scientific Glass Apparatus	T-3801	±.2°F	N/A	N/A
High-Low Temperature Humidity Chamber	Associated Testing Laboratories	ELHH-8-MR/LC	±2°F	8-25-77	10-25-77
High-Low Temperature Humidity Chamber	Associated Testing Laboratories	ELHH-27-MR/LC	±2°F	8-30-77	10-30-77
Sand and Dust Chamber	Bethlehem Corp.	S/D 64	±2°F	5-3-77	11-3-77
High-Low Temperature Chamber	Associated Testing Laboratories	TL-B	±2°F	8-24-77	11-24-77
Shock Test Console	Associated Testing Laboratories	--	±5%	11-16-77	2-16-78
Accelerometer	Endevco Corp.	2271A	±5%	10-7-77	1-7-78
Oscilloscope	Tektronix, Inc.	545A	±3%	10-19-77	1-19-78

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LIST OF APPARATUS (continued)

ITEM	MANUFACTURER	MODEL NO.	ACCURACY	CALIBRATION DATE	CALIBRATION DUE
Vibration System	Ling Electronics	A175	±5%A ±2%F	10-3-77	1-3-78
Accelerometer	Endevoc Corp.	2215E	±5%	10-7-77	1-7-78

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IMMERSION TEST

TEST PROCEDURE

Microphone S/N F, was subjected to an immersion test in accordance with MIL-STD-810C, Method 512.1, Procedure I, as follows.

The test unit was placed in a temperature chmber previously stabilized at 45°C (113°F). After the unit had stabilized, it was immersed in a column of water subh that the uppermost point of the test specimen was 36 ±5 inches below the surface of the water. The temperature of the water was between 13°C (55°F) and 23°C (73°F). The test item remained immersed for a period of 120 minutes.

Following the test, the unit was removed from the water and the exterior surfaces were dried. The unit was returned to JMR Systems for a performance evaluation.

TEST RESULTS

Since the unit was sealed, an internal examination for the presence of water was impossible. Criteria for passage was a post test performance evaluation performed at JMR Systems.

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SALT FOG TEST

TEST PROCEDURE

Microphone, S/N I, was subjected to a salt fog test in accordance with Method 509.1, Procedure I of MIL-STD-810C, as follows.

The unit was suspended within a salt spray chamber by means of a waxed cord. The units were subjected to a dense salt fog atmosphere for a 48 hour period, at an ambient temperature of +35°C (95°F). The salt fog was developed by atomizing a solution composed of 5 parts by weight of sodium chloride (NaCl) dissolved in 95 parts by weight of demineralized water. Distilled water was used for the solution. The pH of the resulting solution was adjusted to a value between 6.5 and 7.2 using either sodium hydroxide (NaOH) or chemically pure hydrochloric acid (HCl). The specific gravity of the resulting solution was within the required range of 1.0268 and 1.0413.

The air used to atomize the salt solution was conditioned by passing it through a column of water whose temperature was maintained at a value of approximately +40°C, (104°F), resulting in an air supply at the atomizer nozzle having a relative humidity of 85% and a temperature of +35°C (95°F). Air pressure at the atomizer nozzle was adjusted to maintain an atomization rate of approximately three quarts of salt solution per ten cubic feet of chamber volume per 24 hour period.

Following completion of the 48 hour salt fog test, the Microphone was removed from the salt spray chamber and examined for evidence of physical damage.

SALT FOG TEST

TEST PROCEDURE (continued)

Accumulated salt deposits were removed from the surface of the unit by means of a gentle wash in running water whose tmeperature did not exceed +38°C (100°F). The test specimen was specifically examined for evidence of metal and finish corrosion.

TEST RESULTS

The unit did not exhibit any physical degradation as a result of the salt fog test. The unit was returned to JMR Systems for a functional test.

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SAND AND DUST TEST

TEST PROCEDURE

Microphone, S/N F, was subjected to a sand and dust test in accordance with MIL-STD-810C, Method 510.1, Procedure I, as follows.

The test set was installed within a sand and dust chamber and the chamber sealed.

The chamber temperature was set to +23°C (73°F). The chamber relative humidity was maintained at less than 22%. The test medium was 140-mesh silica flour. The air velocity within the chamber was adjusted to 1750 $\pm$250 feet/minute during this exposure. The dust feeder was set to control the dust concentration at between 0.1 to 0.5 grams/cubic foot. The unit was maintained at these conditions for six hours.

Following completion of the six hour period, the dust feed was shut off. The chamber air velocity was reduced to between 100 and 500 feet/minute. The internal chamber air temperature was raised from +23°C (73°F) to +63°C (145°F). The chamber relative humidity was maintained at less than 10% during this portion of the test. These chamber conditions were maintained for an overnight period (approximately 16 hours.)

Following tha overnight period, the air velocity in the chamber was adjusted to 1750 $\pm$250 feet/minute. The chamber temperature was maintained at +63°C (145°F). The dust feeder was adjusted to control the dust concentration at a level of between 0.1 and 0.5 grams/cubic foot. These conditions were maintained for six hours. Following the six hour period, the chamber controls were turned off and the units allowed to return to room ambient temperature.

Report No. T-5762-11

SAND AND DUST TEST

TEST RESULTS

There was no damage noted to the unit as a result of the test. The unit was retruned to JMR Systems for post test evaluation.

Report No. T-5762-11

FUNGUS TEST

TEST PROCEDURE (continued)

The mineral salts preparation was sterilized by autoclaving at +121°C (250°F) for 20 minutes. The pH of the solution was adjusted by the addition of 0.01 normal solution of NaOH so that after sterilization, the pH of the salts solution was between 6.0 and 6.5. It should be noted that only reagent grade chemicals were used for preparation of the solution.

The fungus spore solution used the following fungi:

Fungi	ATTC No.	NLABS No.
Aspergillus niger	9642	386
Aspergillus flavus	9643	380
Aspergillus versicolor	11730	432
Penicillium funiculosum	9466	391
Chaetomium globosum	6205	459

In preparing the solution, the subcultures were incubated at +29°C (84°F) for a period between 7 and 20 days. The spore suspension of each of the five fungi were prepared by pouring into one subculture of each fungus a sterile 10 ml portion of distilled water, By using a sterile platinum of nichrome inoculating wire, a portion of the culture growth was scraped out of the test tube container. The spore charge was placed into a terile 125 ml glass stoppered Erlenmeyer flask.. The flask contained 45 ml of distilled water and 10 to 15 solid glass beads, 5 mm in diameter. The flask was vigorously shook to liberate the spores from the fruiting bodies and to break the spore clumps. The suspension was filtered through a thin layer of sterile glass wool in a glass funnel into a sterile flask in order to remove mycelial fragments.

Associated Testing Laboratories, Inc.
Wayne, New Jersey 07470
Burlington, Massachusetts 01803

FUNGUS TEST

TEST PROCEDURE (continued)

The spore suspension was centrifuged aspetically. Resuspend the residue in 50 ml of distilled water and centrifuged again. The spores from each fugi were washed in this manner a total of three times. The final washed residue contained 1,000,000 ±200,000 spores per ml as determined with a couting chamber; as it was diluted with sterile mineral salts. This process was repeated for each organism used in the test. Equal volumes of the resultant spore suspension were blended to obtain the final mixed spore suspension. A prepared spore suspension was not allowed to stand more than four days prior to use in the test.

Three pieces of sterilized filter paper, one inch square, were placed in the incubation chamber. The filter paper was placed onto hardened mineral salts agar in separate petri dishes. These samples were inoculated with the spore suspension by spraying from a sterilized atomizer. The entire surface was moistened with the spore suspension. In addition, a number of known susceptable substrates were inoculated. These items were three pieces of preservative free vegetable tanned leather and protein glue bonded cork.

The selected part was placed into the chamber. The specimen plus the control samples were inoculated by spraying the surfaces by means of a sterilized atomizer. The spore supension was liberally sprayed over the entire surface ot the unit. The spor suspension was also sprayed onto the leather and cork control samples. The incubation chamber was then sealed. The incubation chamber was maintained at +29°C (84°F) and 95% relative humidity. After an incubation period which lasted 14 days, the chamber was opened and the control samples examined. It the samples did not show an abundant growth, the entire test was to be repeated. The controls showed satis-

Report No. T-5762-11

FUNGUS TEST

TEST PROCEDURE (continued)

factory fungus growth and the chamber was resealed. Testing was then continued until a total time of 28 days had elapsed from the time of inoculation.

Upon completion of the 28 day incubation period, the test specimen was removed from the chamber and examined for evidence of fungus growth.

TEST RESULTS

The test specimen did not show any evidence of fungus growth.

SINUSOIDAL VIBRATION TEST

TEST PROCEDURE

Microphone, S/N J, was subjected to a sinusoidal vibration test in accordance with written instructions from JMR Systems, as follows.

The unit was attached to the vibration test fixture which, in turn, was securely attached to the table of a vibration exciter. A control accelerometer was mounted to the fixture for controlling the input vibration amplitude to the unit. The unit was then subjected to vibration cycling over the frequency range of 5 to 500 Hz at the levels given below.

Table I

Frequency (Hz)	Peak Amplitude
5 - 20	0.1 inch d.a.
20 - 500	± 2g's

The frequency range of 5 to 500 Hz and return to 5 Hz was traversed during a time interval of 15 minutes. The vibration cycling time was two hours.

The above procedure was performed in the horizontal axis only.

TEST RESULTS

No physical damage was noted following the vibration test.

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HUMIDITY TEST

TEST PROCEDURE

Microphone, S/N H, was subjected to the humidity test in accordance with MIL-STD-810C, Method 507.1, Procedure II. The following describes the test as it was performed.

The unit was installed within a high-low temperature, humidity chamber. A stainless steel hood was placed over the specimen to prevent chamber wall condensate from impinging onto the unit under test. The chamber was then sealed.

The Microphone was first subjected to a 24 hour drying cycle at a temperature of +129°F. Following this, the unit was subjected to a 24 hour conditioning cycle at a temperature of +73°F at a relative humidity of 50 ±10%. When the second conditioning cycle was completed, the unit was functionally checked out. The unit was then subjected to five continuous 48 hour cycles, throughout which the relative humidity was maintained at 94 ±4% at all temperatures below +29°C (+84°F) and at a constant +29°C dew point (wet bulb tmeperature) at all temperatures above +29°C. The test cycle is described as follows:

> The chamber temperature was raised to +149°F over a four hour period. The chamber was maintained at +149°F for the next 8 hours. The chamber temperature was lowered from +149°F to +86°F over the following four hour period. The chamber was maintained at +86°F for the next 21 hours. The chamber was decreased to +68°F in one hour period. The chamber was maintained at +68°F for the next four hours. The chamber temperature was raised back to +86°F in a one hour period and held at +86°F for five hours.

HUMIDITY TEST

TEST PROCEDURE (continued)

Following the final 48 hour cycle, the chamber temperature was adjusted to +73°F. The chamber relative humidity was set to 50 $\pm$10%. These conditions were maintained for 24 hours. After completion of the 24 hour exposure, the Microphone was removed from the chamber and subjected to a checkout.

TEST RESULTS

There was no evidence of physical damage observed as a result of the humidity test. The functional tests performed by JMR Systems were reported to be satisfactory. It was noted that both ends of the Micropohe had delaminated slightly.

SHOCK (DROP) TEST

TEST PROCEDURE

The Microphone was subjected to a shock (drop) test in accordance with written instructions from JMR Systems, as follows.

The unit was subjected to twelve impacts from a height of six feet onto a concrete floor. The drop height was measured from the impact surface of the unit to the concrete floor.

Following the drop test the specimen was examined for damage.

TEST RESULTS

After completion of the shock test the unit exhibited delamination on the end of the microphone.

Report No. T-5762-11

APPENDIX B

ELECTROMAGNETIC SUSCEPTIBILITY DATA

Report No. 2714

Revision ______

REPORT OF

ELECTROMAGNETIC INTERFERENCE

TEST ON

JMR SYSTEMS, INC.

NOISE CANCELING ELECTRET MICROPHONE

TEST PERFORMED BY

SANDERS ASSOCIATES, INC.

95 CANAL STREET

NASHUA, NEW HAMPSHIRE

CONTRACT NO.

	DATE	SIGNATURE
TEST INITIATED	9/19/77	
TEST COMPLETED	9/19/77	
REPORT WRITTEN BY		R. [illegible]
TEST TECHNICIAN		
TEST ENGINEER		
SUPERVISOR		R. [illegible]
GOVERNMENT REP. (If Applicable)		
FINAL RELEASE		

ELECTROMAGNETIC INTERFERENCE REPORT TEST SUMMARY SHEET

TEST ITEM: Noise Canceling Electret Microphone	REPORT NO. 2714	DATE TEST COMPL. 9/19/77 DATE REPT. COMPL.
MANUFACTURER: JMR SYSTEMS, INC.	SPECIFICATION MIL-STD-461A, Notice 4	

SUMMARY OF TEST RESULTS

TEST METHOD	TITLE	SPEC. PARA.	REMARKS	PASS	FAIL
CS01	Conducted Susceptibility, 30 Hz to 50 kHz DC Power Leads	6.6	Not required		
CS02	Conducted Susceptibility, 50 kHz to 400 MHz, AC and DC Power Leads	6.7	Not required		
RS03	Radiated Susceptibility, 10 kHz to 400 MHz, Electric Field	6.20			X

SUMMARY OF REPORT: RS03 Harmonic distortion at the microphone output exceeds 1% at various frequencies between 23 MHz and 395 MHz.

1.0 ADMINISTRATIVE DATA

1.1 Purpose/Reason for Test

To determine if JMR Systems, Inc. Noise Canceling Electret Microphone complies with the limits defined in the applicable portions of MIL-STD-461A, Notice 4.

1.2 Description of Test Sample

The unit tested was a JMR Systems, Inc. Noise Canceling Electret Microphone.

1.3 Disposition of Test Sample

Returned to JMR Systems, Inc. by their personnel.

1.4 References

Test Plan 2541 Electromagnetic Compatibility Test Procedure:

DF-AF-0191 (A)	Development Specificiation for Noise Canceling Electret Microphone.
MIL-STD-461A, Notice 4	Electromagnetic Interference Characteristics Requirements for Equipment.
MIL-STD-462, Notice 3	Electromagnetic Interference Characteristics, Measurement of.
MIL-STD-463, Notice 1	Definitions and Systems of Unit Electromagnetic Interference Technology.

2.0 TEST FACILITY DESCRIPTION

2.1 Shielded Room

The Radio Frequency shield room used for EMI testing conforms with the design criteria of MIL-E-8881, Table IIB per Table 1, Double Shield cell type, solid metal Class C per Table II. The room size is 6.1 meters X 3.0 meters X 2.4 meters. Door size clearance is 2.0 meters by 1.8 meters.

2.2 Power Availability

Power available inside the room is 115 VAC, 60 Hz, 1 phase, and 28 VDC. Power is routed through Powerline Filters 1B40-60, 60 ampere, providing 100 dB attenuation from 14 kHz to 10 GHz.

2.3 Enclosure Attenuator Characteristics

The attenuation characteristics of the enclosure when tested in accordance with MIL-STD-285 is 70 dB for magnetic Field and 100 dB for electric field and plane wave.

2.4 Ground Plane

The microphone was installed over a copper ground plane (solid plate), measuring 4.9 meters X 0.92 meters. The ground plane is bounded to the shielded room wall at intervals of less than 0.90 meters with a d. c. bonding resistance of 0.2 milliohms.

3.0 TEST EQUIPMENT CALIBRATION

3.1 Field Intensity Meters

The principle means of determining frequency and amplitude during the test will be one or more of the following field intensity meters:

Model No.	Mfr.	Frequency Range	Frequency Accuracy	Amplitude Accuracy
EMC-25	Fairchild	14kHz-1GHz	±2%	±1.5 dB
Calibrated every 12 months				
NF-105	Singer/Empire	14kHz-1GHz	±2%	±1 dB
Basic Unit				

TX - 12 months TA - 12 months T1 - 12 months

T2 - 12 months T3 - 12 months

3.1 Field Intensity Meters (Cont.)

These instruments are calibrated by the Sanders Associates Instrumentation Calibration/Standards Laboratory, which operates a government approved calibration program in accordance with MIL-C-45662A, "Calibration System Requirements". The calibrating equipment accuracy required by MIL-C-45662A is several orders of magnitude greater than that of the EMC instrumentation listed above. This ensures the greatest possible frequency and amplitude data accuracy.

3.2 Transducers

All antennas--(with one exception)--use the correction factors supplied by their respective manufacturers. The single exception is the Empire VA-105 41-inch vertical rod antenna (150 kHz to 30 MHz) which is calibrated every six months by the Sanders' Calibration Laboratory.

3.3 Signal Sources

A variety of signal sources are used to develop the r. f. environment for system susceptibility tests. The field intensity is monitored by the field intensity meters described above, and so the signal source was not a primary consideration in determining the accuracy of measurement.

The signal sources are calibrated by the S/A Instrument Calibration/Standards Laboratory on a 12 month cycle.

3.4 Test Sample Operation and Monitoring

The microphone and artificial voice was installed inside the shield room over the ground plane. The associated exercise equipment and susceptibility monitoring meters were located outside the shield room.

During EMI testing the microphone was exercised with an artificial voice of 1000 Hz, driven at a sound pressure level of 103 dB measured 1/4 inch from the sound source. The following equipment was furnished by JMR Corp.

B & K Model 2010 Analyzer

B & K Model 4219 Artificial Voice
HP Model 400 EL Voltmeter or equivalent.

While in normal operation the DC current measured in the positive lead of the 9 VDC input did not exceed 2 ma. A Triplett 630 PL ammeter was installed in series with the +9 VDC power lead.

The voltage measured across the DC return lead and the 150 ohm resistor in the position lead did not change by more than 3 dB. An HP 400 EL Voltmeter model was used.

The microphone - amplifier was monitored for harmonic distortion at the microphone output not to exceed 1%. The harmonic distortion was monitored with a 565 Oscilloscope.

APPENDIX A

TEST METHOD CS01

CONDUCTED SUSCEPTIBILITY

DC POWER LEADS

30 Hz to 50 kHz

4.0 CS01 CONDUCTED SUSCEPTIBILITY, 30 Hz to 50 kHz POWER LEADS

a) Test Procedure

This test was not performed because the test frequency range is the same as the microphones operating range. The CS01 test level requires the injection of signal levels on the DC leads that are greater than the normal operating levels.

Test Equipment

Description	Model/Mfg.	Serial No.	Cal Date
Oscillator	HP200S Hewlett Packard	7153	N/A
Power Amplifier	M0100 Bogen Presto	J52	N/A
Transformer	6220-1 Solar	N/A	N/A
Voltmeter	630PC Triplett	3905	N/A

APPENDIX B

TEST METHOD CS02

CONDUCTED SUSCEPTIBILITY

DC POWER LEADS

50 kHz to 400 MHz

5.0 CONDUCTED SUSCEPTIBILITY, 50 kHz to 400 MHz, POWER LEADS

a) Test Procedure

This test method required that Line Impedance Stabilization Networks be installed in series with the 9 VDC and return power leads. The CS02 test signal is injected through a signal port on the LISN.

This test cannot be performed because the LISN in series with the 9 VDC power lead changes the required impedance of 150 ohms.

b) Test Equipment

Model	Nomenclature	Serial No.
HP606	Signal Generator	7055
HP608	Signal Generator	1091
EMI-F-0431	LISN 10 kHz to 10 MHz	N/A
91221-1	LISN 10 MHz to 400 MHz	N/A
NF-105	EMI Meter	2160
F-50	Current Probe	101
LF-105	Line Probe	N/A

APPENDIX C

TEST METHOD RS03

RADIATED SUSCEPTIBILITY

ELECTRIC FIELD

10 kHz to 400 MHz

6.0 RADIATED SUSCEPTIBILITY, 10 kHz to 400 MHz, ELECTRIC FIELD

a) Test Equipment

Description	Model/Mfg.	Serial No.	Cal Date
EMI Meter	NF-105 Empire	2160	11/76
Oscillator	HP200S Hewlett Packard	212-00620	N/A
Signal Generator	HP606 Hewlett Packard	038-03786	5/77
Power Amplifier	M0100 Bogen	J52	N/A
Power Oscillator	404A Microdot	32	1/77
Power Oscillator	406A Microdot	87	9/77
Power Oscillator	125 Airborne Inst. Lab.	12510	N/A
Vertical Antenna	VR-1-105 Empire	181	5/77
Vertical Antenna	VA-105 Empire	195, 372	4/77, 6/77
Biconical Antennas	7825 Honeywell	N/A	N/A
Cone Antennas	93490-1 Stoddart	N/A	N/A
Oscilloscope	545 Tektronix	4385	6/77

b) Test Procedure

The radiating antenna was placed in front of the test sample at a distance of 1 meter.

The Noise Canceling Electret Microphone was then tested with a 1000 Hz, input and exposed to the following radiated field intensity levels:

10kHz to 1.9MHz	1.0 V/M
2.0MHz to 29.99MHz	5.0 V/M
30 MHz to 400 MHz	10.0 V/M

During the test the susceptibility carrier was modulated 50% with a 1000 Hz tone. When a failure occurred the frequency and threshold level were recorded. The test was performed as described in paragraph 9.0 of Test Plan 2541.

c) Test Results

Harmonic distortion at the microphone output exceeded 1% at various frequencies between 23 MHz and 395 MHz. Worst case was at 135 MHz, while radiating with a vertical biconical, the threshold level was 1.3 Volts. Detail test results are shown on data sheet 1.

d) Conclusions

JMR Systems Corporation Noise Canceling Electret Microphone does not comply with RS03 requirements.

EMC DATA SHEET

DATE: 9-19-77 REPORT NO: ________ DATA SHEET ____ OF ____

ITEM TESTED: NOISE CANCELING ELECTRET MICROPHONE

TEST PERFORMED: RS03 RADIATED SUSCEPTIBILITY 14KHZ TO 400MHZ

TEST CONDITIONS: 1000 HZ INPUT TO MICROPHONE

TEST EQUIPMENT: ________

PERFORMED BY: RL

FREQ. MHZ	RAD FLD V/M	REQ V/M					
.014	1.0	1.0					
TO	1.0	1.0					
1.9	1.0	1.0					
2.0	5.0	5.0					
TO	5.0	5.0					
22	5.0	5.0					
23.0	2.5	5.0		DISTORTED			
.							
45	5.0	10		DISTORTED			VERT BICON
105	8.0	10		DISTORTED			
135	1.3	10		DISTORTED			
45	2.0	10		DISTORTED			HORIZ BICON
72	1.5	10		DISTORTED			
290.0	3.0	10		DISTORTED			
310.0	4.0	10		DISTORTED			
330.0	9.0	10		DISTORTED			
395.0	3.0	10		DISTORTED			